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VENTILATION IN RELATION TO MENTAL WORK

BY

E. L. THORNDIKE, W. A. McCALL
AND J. C. CHAPMAN

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VENTILATION IN RELATION TO MENTAL WORK

INTRODUCTION

By EDWARD L. THORNDIKE

The experiments reported in this monograph were all carried on under the auspices of the New York State Commission on Ventilation* with the aid of a fund given by Mrs. Elizabeth Milbank Anderson. The authors are indebted to the members of the Commission for criticisms of the work while it was being planned and during its course and to many of the investigating staff for co-operation. The experiments reported here were parts of an organized plan for the most economical use of the Commission's laboratory, physiological, psychological and medical data often being obtained during the same day. Within the limitations thereby set, the effort was made to find out important facts to serve as a basis for the policy of ventilating schools, shops, offices, and the like so far as concerns the mental welfare of their workers. The chief aims were to measure the effect of heat and expired air upon the quantity and quality of the mental products produced per unit of time, and upon the readiness of individuals to work. Certain statements made by them as to their felt fitness for work and general well-being will also be reported here.

The practice of ventilation seeks to secure not only mental efficiency, and comfort as a means to efficiency, but also comfort for its own sake, including the gratification of certain specially refined tastes. The experiments reported here are little concerned with the personal enjoyment of the subjects save in so far as indirectly it influenced the products which they produced. Further, the effects of dryness and wetness and of cold are left unmeasured by the present experiments, though it is hoped that a report concerning the former can be made later.

We have measured the effect of certain mental activities chosen to represent fairly the mental work of schools and offices, and at

*C. E. A. Winslow, Chairman, D. D. Kimball, Frederick S. Lee, James Alexander Miller, M. D., Earle B. Phelps, Edward Lee Thorndike; George T. Palmer, Chief of Investigating Staff, Joseph Herzstein, Secretary.

the same time to be measurable with reasonable accuracy and convenience. As a consequence of the second requirement, forms of work demanding an extremely complex organization of mental material, such as writing a sermon or planning a business campaign, and forms of work involving social restraints, personal impressiveness and conflict, such as teaching a class, selling goods to a customer, or keeping one's temper in annoying human encounters, are not represented. The tests used are all of work with ideas, symbols and mechanisms, not of work with persons.

EXPERIMENT I

THE EFFECT OF CONDITIONS OF THE AIR ON MENTAL WORK, THE CONDITION BEING CHANGED DAILY

By J. C. CHAPMAN

General Conditions

The object of this research was to investigate the effect of certain atmospheric conditions upon mental efficiency. For this purpose the subjects employed were tested in various functions under varying external conditions of temperature and humidity and air circulation. The experiment was so arranged as to eliminate practice and individual differences; the method of the experiments will be described in detail later. The dates of the experiments were as shown in Table 1.

Physical Conditions

The experiments were performed at the Laboratory of the New York State Commission on Ventilation, where the complete ventilation plant had been fitted. A full description of the mechanical part of the plant is presented elsewhere;* it will be sufficient to give here a general account of the arrangement.

The plant consisted of two rooms:

1. Observation room (thermally insulated).
2. Control room.

In the control room was the mechanical part of the plant, which was capable of supplying, at desired rates, air of required temperature and humidity to the observation room. There was also a refrigerating plant capable of cooling the room in very short periods. In addition, fans were employed in the observation room itself for rapid circulation of the air. By means of this plant it was possible

*D. D. Kimball and G. T. Palmer: The Experimental Laboratory of the New York State Commission on Ventilation: Transactions of the American Society of Heating and Ventilating Engineers, 1915, Vol. 21, pp. 135–207.

to maintain a comparatively steady physical condition of the atmosphere for any length of time.

TABLE 1

PROGRAM OF WORK; EXPERIMENT I

1913, Nov. 10–14 " Nov. 17–21 " Dec. 8–12	Preliminary tests.
" Dec. 15–19 1914, Jan. 26–30 " Feb. 2–6 " Feb. 9–13 " Feb. 16–20	First five weeks of Experiment I.
" Feb. 23–27 " Mar. 2–6 " Mar. 9–13 " Mar. 17–20* " Mar. 23–27	Second five weeks of Experiment I.

The conditions to be contrasted in Experiment I were as shown in Table 2. It should be noted, however, that, as shown later in Table 3, the CO_2 percentages did not rise much, even when the same air was recirculated throughout the day. The recirculation was found necessary by those operating the plant in order to maintain the other conditions required. Condition C differs from condition A therefore, not by a markedly less CO_2 content, but only by whatever differences existed between outside and recirculated air under the conditions of the plant's operation.

TABLE 2

DESIRED PHYSICAL CONDITIONS OF THE OBSERVATION ROOM DURING EXPERIMENT I

Movement	*Air Supply*	*Relative Humidity*	*Temperature*
A. No fans	No outside air supplied	80%	86 F (30C)
B. 4 fans at high speed	No outside air supplied	"	"
C. No fans	45 cu. ft. per min. per person of outside air	"	"
D. No fans	No outside air supplied	50%	68 F (20C)
E. No fans	45 cu. ft. per min. per person of outside air	"	"

* One day omitted.

Table 3 gives a detailed account of the conditions actually realized day by day.

TABLE 3

RECORDED ROOM-CONDITIONS DURING EXPERIMENT I

R = recirculated air. F = outside air introduced. Beg., Mid., and End refer to the beginning, middle, and end of the four-hour period from 2 to 6 p. m.

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
			Cu. ft. per min.				*CO_2 parts per 10,000*	
Subjects	*Date*	*Air Supply*	*per person*	*Humidity*	*Temperature*	*Beg.*	*Mid.*	*End*
Squad I	12/15	R	50	80	86			
	12/16	R	50	77	87.5			
	12/17	F	48	76	87.5			
	12/18		0	36	74			
	12/19	F	48	48	68			
Squad II	1/26			cir. 35	cir. 70		Normal classroom	
	1/27	F	56	58	66.5			
	1/28	R	38	65	89			
	1/29	R	55	74	88			
	1/30	F	55	68	86.5			
Squad III	2/2	F	44	76	86.5			
	2/3	R	44	48	72.5			
	2/4	F	45	42	67.5			
	2/5	R	48	70	86.5			
	2/6	R	48	72	86.5			
Squad IV	2/9	R	45	68	88.5			
	2/10	F	20	78	85			
	2/11	R	48	48	69			
	2/12	F	44	44	67			
	2/13	R	48	80	85.5			
Squad V	2/16	F	45	52	68			
	2/17	R	50	76	86.5			
	2/18	R	40	74	87			
	2/19	F	45	72	85.5			
	2/20	R	20	35	74			
Squad VI	2/23	R	45	75	87		5.5	7.5
	2/24	R	43	74	86.5			8.0
	2/25	F	40	73	87			6.0
	2/26	R	40	52	67.5			9.0
	2/27	F	45	47	68.5			8.0
Squad VII	3/2	R	40	54	67		12.0	7.0
	3/3	F	45	48	68			5.0
	3/4	R	40	70	88.5			7.0
	3/5		0	47	88.5		16.0	26.0
	3/6	F	45	78	86			12.0

TABLE 3—*Continued*

1	2	3	4	5	6	7	8	9
			Cu. ft. per min.				*CO2 parts per 10,000*	
Subjects	*Date*	*Air Supply*	*per person*	*Humidity*	*Temperature*	*Beg.*	*Mid.*	*End*
Squad VIII	3/9	F	45	77	86.5			4.5
	3/10	R	40	53	68			7.5
	3/11	F	45	51	68.5	6.5		6.0
	3/12	R	40	74	87.5			
	3/13	R	30	68	88	4.5		9.0
Squad IX	3/16		Omitted					
	3/17	R	40	50	86			
	3/18	R	40	76	85.5			6.5
	3/19	R	40	43	70			
	3/20	F	45	54	67.5	6.0		6.5
Squad X	3/23	F	45	54	67.5			
	3/24	R	35	45	69			
	3/25	R	43	75	84.5	4.5		8.5
	3/26	F	45	84	84.5			
	3/27	R	40	81	85.5	6.0		

The subjects were men students of the College of the City of New York. No selection of the subjects was made on the basis of ability —the subjects themselves volunteered for the work and were paid upon a commercial basis. The only test which each subject had to undergo before receiving employment was to name colors and perform mental multiplication of three-place by three-place numbers. It may be said that out of approximately sixty subjects, these tests only eliminated three individuals.

Owing to the size of the observation room and the difficulty of controlling its conditions, it was not feasible to test more than four subjects at any one time. The final arrangement was to have for each complete experiment five squads of four subjects, each squad to occupy the room for four hours a day on five days of each week. The experiment thus extended over a period of five weeks. Each squad of four subjects formed a distinct unit, and when its own particular week had elapsed, the results which it gave were complete.

There were five days during which each squad occupied the room. On each of these days a different physical condition was maintained throughout the four-hour test period. Throughout the five weeks of each half of the experiment the distribution of these various conditions was so arranged that the favorable and unfavorable conditions came in all possible orders during the week period. Thus at the end of the five weeks any particular condition had occurred on

the first day in one week, the second day in another week, the third day in another week, the fourth day in another and the fifth day in another week. Such an arrangement was necessary in order to eliminate the factor of practice.

The Tests

Color-naming. The subject was provided with a Woodworth-Wells blank on which were printed in random order one hundred small squares of varying primary colors; nothing of the nature of discrimination of shades was necessary. The subject was made to name each of the one hundred squares in as rapid succession as possible. The time taken to name the complete series was measured by the experimenter. In the case of any misnaming of the color the subject was stopped and made to return to the point at which the mistake arose, in this way adding to the time taken for the test. The scores recorded are the times taken to name correctly the 100 colors.

Cancellation of 2's. The subject was provided with a Woodworth-Wells cancellation sheet, in which there are a series of random groupings of five figures. In this sheet a certain specified number, 2 in the first instance, had to be cancelled. The object of the experiment was to omit as few cases of the specified number as possible and to complete a maximum amount of cancellation in the period allowed—60 seconds. The numerical results as given in the tables are calculated on the following arbitrary basis:

2 (numbers cancelled correctly) —2 (numbers wrongly omitted) —3 (numbers wrongly marked).

From this method of scoring it will be noticed that additional speed may reduce one's score if gained at the expense of accuracy. On the other hand, additional speed may outweigh complete accuracy. This was pointed out to the subjects at the commencement of the work, the scores from day to day revealing to what extent speed was being gained at the expense of accuracy.

Cancellation of 3's. The above test was repeated, cancelling 3's instead of 2's. In all other particulars the two tests were similar.

Hard Opposites. The subject was provided with a list of fifty words as used by Hollingworth, of which the opposites in each case had to be named; a certain range of choice of opposites was allowed. The object of the experiment was to complete this list in a mimimum time. In the case of the misnaming of any opposite, the subject

was stopped and made to return to the point at which the mistake arose: at any time when more than 15 seconds was taken to name any particular opposite, the subject was told the correct word. The time taken to complete the list with the necessary corrections and promptings was measured. After the first test or so, it rarely happened that any prompting was necessary, though throughout, owing to the high speed, occasional mistakes arose. A different arrangement of the words was used in each of these tests. The score as given in the tables is the time taken to name the fifty opposites correctly, under the above conditions.

Addition. The subject was provided with two sheets of the set of blanks containing columns of ten one-place numbers as devised by Thorndike. Different sheets were used from day to day to prevent possible memorizing on the part of the subjects.

The object of the test was to complete the maximum number of correct additions in the time allotted—10 minutes. The answers were written at the base of the columns. If an answer was wrong no credit was given for that column. The results stated in the tables are the number of columns added correctly in 10 minutes.

Mental Multiplication. The subject was provided with a sheet containing a random selection of pairs of three-place numbers arranged by putting any three-place number containing no digit lower than three and repeating no digit, with another such number. These pairs had to be multiplied mentally, nothing being written down until the final product was obtained. The subjects were permitted to look at the problem continuously. The period allowed for the tests was 20 minutes. The method of scoring was as follows: Each example done correctly was credited 10, minus 1, 2, 3, 5, for one, two, three, and four figures wrong respectively. Zero credit was given in an example with less than two figures correct. The score recorded in the tables is the product produced in 20 minutes after deduction for errors on the above scale.

The tests were performed each week on the squad of four subjects, on the days from Monday to Friday inclusive. The Saturday previous was devoted to a preliminary trial, in which each squad was put through the series of tests. The rules were explained, while added uniformity was obtained by putting in writing before each subject the object of the test, and the method of scoring. Any questions which arose on the trial day were answered, so that on the days of the test no misunderstanding could arise. By devoting a

little time on this preliminary day a considerable amount of irregularity was avoided in the initial measurements.

Each afternoon of the week was divided into two sections, the periods falling between 2:30 and 3:45 and 4:15 and 5:30 p. m., respectively. In this manner there were ten periods devoted to the experiment during the five days. During each of these ten periods the whole series of mental tests was employed. The distribution of time meant that the tests were separated by 1¾ and 23 hours.

A program of the work of each day is shown below.

2:00–2:30 p. m.	physiological tests
2:30–3:45 p. m.	psychological tests
3:45–4:15 p. m.	physiological tests
4:15–5:30 p. m.	psychological tests
5:30–6:00 p. m.	physiological tests

The results of the physiological tests will be published elsewhere.

A full record of the scores made by each individual will be found in Tables 6 to 12. In addition to the tests at the end of each afternoon the subject was made to report on his physical condition. The scale of the report was as follows:

5. I feel as comfortable as I ever do, or nearly so.
3. I feel about as I usually do at the close of an afternoon of hard mental work.
1. I feel as uncomfortable as I would with a severe headache or an attack of the grippe.
4. My condition is about halfway between 3 and 5.
2. My condition is about halfway between 1 and 3.

Soon after these experiments started, it became apparent that there was an uncertainty about the meaning of this scale. On the hot and humid days, it repeatedly happened that a subject would ask if he should report on his condition just at the moment or upon what he knew his condition would be after returning to the fresh air outside the room. The decision was made that the report should be based upon the more or less permanent condition rather than upon the temporary condition, such as would be produced at the time by the depressing effects of a high temperature combined with high humidity. This arbitrary decision should be noted, if correct interpretation is to be given to the report of the condition of the subject. Had this report been based upon present feelings, there would have been a much more noticeable difference in the reports on the days where the good and bad conditions were produced. If, instead of physical condition, the satisfyingness of the work had been

measured on a suitable scale, the difference between the reports on the hot and normal days would, in the opinion of the writer, have been large.

Method of treating the numerical results of the five-week period. At the end of the five weeks, each of the five conditions of ventilation has occurred five times, once in each week on varying days from the first to the last day. If the scores made on the five days when any particular condition was produced are added and averaged, an estimate is obtained of the efficiency of all of the twenty individuals under this particular condition. Similarly for the other four conditions, by summation and taking averages we obtain measures of the efficiency under each of the conditions. Owing to this arrangement of the days it will be observed that the influence of practice is largely equalized. In Table 4, the scores obtained under each of the five conditions by the twenty individuals have been averaged.

TABLE 4

AVERAGE SCORES IN EACH TEST UNDER EACH CONDITION OF VENTILATION; EXPERIMENT I; FIRST FIVE WEEKS

Condition of Room	*E**	*D*	*B*	*C*	*A*	
Fans Supply of air Temperature Humidity	No F. 68° F. 50%	No R. 68° F. 50%	High speed R. 86° F. 80%	No F. 86° F. 80%	No R. 86° F. 80%	*P.E.'s of Column E.*
Color (time)	49.2	48.5	48.2	48.5	48.9	.54
Opp (time)	52.6	52.6	54.0	57.1	55.4	1.3
Cancel (time)	101.5	103.1	100.7	100.7	102.1	1.0
Addition	74.4	76.5	75.6	74.8	76.0	2.8
Mental Multiplication	56.6	60.5	62.8	59.7	57.2	2.4
Report on subject's condition by himself	3.6	3.9	3.2	3.0	2.5	.07

* The P.E. of the average scores of this column is shown in the last column. For each test the P.E. remains of the same order.

FIRST FIVE-WEEK PERIOD

These results show that, within the limits of experimental error, efficiency when tested by the quantity and quality of the product produced per unit of time is independent of the external conditions

of ventilation which were artificially produced in this experiment. Though the subject suffered considerable inconvenience and discomfort from the atmospheric conditions on three days of the week, yet the scores on these days were as high as on the other days. In other words, the difference between the conditions is that of comfort and satisfyingness and not that of quantity and quality of product produced.

Of the three days when the temperature and humidity were high the day when the fans were directed on the subjects was the least unpleasant—the relief from the rapid circulation of the air caused by them was great, keeping the upper part of the body, including the face, reasonably cool. On the other two days, the subjects were in a continuous state of perspiration; the air was hot and heavy, having a tendency to produce sleepiness and depression.

During the first five weeks of Experiment I, the subjects were provided with light under-shirts and sweaters. On the warm days they were allowed to remove the sweaters, leaving only the light undershirt. This approximates to the conditions in ordinary life, for individuals working for any length of time in hot rooms will eventually dress accordingly. Even when the lightest clothes were worn on the two days when it was 86° and no fans were used, it was impossible to keep cool, and judged by the usual standards of mere physical well-being, the general comfort was greatly reduced.

Experiment I, Second Five Weeks

Experiment I was repeated, the only differences in procedure being:

1. The substitution of typewriting for color-naming and cancellation tests.
2. The subjects were made to wear the sweaters on the hot days as well as on the cool days.

Rules for Typewriting Test. The subjects were given sufficient preliminary practice with the machines to enable them to understand their working. On the days of the test during each of the ten periods, ten minutes was devoted to typewriting. Short pieces of uniform simple prose were used as the matter for writing, different extracts being employed at each of the ten tests. The method of scoring was as follows: One unit was given for each correct line of the test, the lines being reckoned from the extracts which were so chosen as to give lines of equal length; one-tenth of a unit was subtracted for

each word in which an error was made. Mistakes in spacing and serious mistakes in punctuation were also counted as errors which deducted .1 from the score.

Owing to one of the weeks being broken, only four conditions were produced the necessary five times to eliminate the practice effect. In Table 5 the results are presented in the form previously used.

TABLE 5

AVERAGE SCORES IN EACH TEST UNDER EACH CONDITION OF VENTILATION: EXPERIMENT I, SECOND FIVE WEEKS

Condition of Room	*E**	*D*	*B*	*A*	
Fans	No outside air	No R.	High speed R.	No R.	P.E. of Col. E.
Supply of air					
Temperature	68° F.	68° F.	86° F.	86° F.	
Humidity	50%	50%	80%	80%	
Test					
Opposites (time)	58.5	62.5	54.2	57.4	1.7
Addition	68.8	65.3	69.1	70.0	2.2
Mental Mult.	52.6	45.9	58.8	56.4	2.4
Mental Mult.†	50.2	46.6	47.5	50.8	
Typewriting	88.2	84.4	89.4	86.2	3.6
Report on subject's condition by subject himself.	3.8	3.8	3.2	3.0	0.9

* The P.E.'s of the values of this column are shown in the last column. For each test the P.E. remains of same order.

† Results of two individuals are omitted whose improvements were abnormal so that the factor of individual differences is not eliminated.

The result of the second five weeks, in which the subjects were made to wear sweaters on the hot days as well as on the normal days, confirms the previous result. When the probable errors of the averages are considered, it appears that there is no diminution in the scores under the abnormal conditions of temperature and humidity (86° F and 80% rel. hum.). If the numerical data are interpreted strictly, it would seem that there is actually a slight increase under the bad condition.

EXPLANATION OF TABLES 6 TO 12

Tables 6 to 12 give the detailed scores for both the first and second five-week experiments. Squads I–V inclusive represent the first experiment, while Squads VI–X inclusive represent the second

experiment. In the second experiment one of the weeks was broken. In every case the letters E and L refer to early and late periods of the day's session. The dates in these tables correspond to the dates in Table 3. All scores reported here are net scores, a fair allowance having been made for errors. The following key, which is for all the tables from 4 to 10, gives the order of the conditions for each squad. The figure 1 under any condition means that that condition came on the first day of that squad's practice, and so on.

	E	*D*	*B*	*C*	*A*
	2422	1122	4133	2433	1133
Fans	No outside air	No R.	High speed R.	No outside air	No R.
Supply of air					
Temperature	68° F.	68° F.	86° F.	86° F.	86° F.
Humidity	50%	50%	80%	80%	80%
Squad I Day	5	4	2	3	1
Squad II "	2	1	4	5	3
Squad III "	3	2	5	1	4
Squad IV "	4	3	1	2	5
Squad V "	1	5	3	4	2
Squad VI "	5	4	2	3	1
Squad VII "	2	1	4	5	3
Squad VIII "	3	2	5	1	4
Squad IX "	4	3	1		2
Squad X "	1	2	3	4	5

TABLE 6

Color Naming: TIME IN SECONDS TAKEN ON EACH SUCCESSIVE DAY BY NINETEEN INDIVIDUALS

Each early and late period has two divisions. The upper row always represents the first division

Squad I	*12/15*		*12/16*		*12/17*		*12/18*		*12/19*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Grossberg	58	56	53	50	50	48	46	46	43	47
	58	54	53	50	44	54	49	49	52	49
Hanson	50	50	45	45	44	44	42	44	45	46
	46	47	44	42	45	42	44	44	47	44
Schachter	63	60	52	57	54	54	55	57	54	58
	70	64	59	57	61	56	62	62	60	62
Fried	44	43	41	44	41	40	40	39	41	38
	44	44	47	43	43	37	38	40	40	41

TABLE 6—*Continued*

Squad II	*1/26*		*1/27*		*1/28*		*1/29*		*1/30*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Schroeder.....	57	54	53	51	48	51	46	52	47	49
	54	52	49	52	47	51	50	54	51	50
Frey.....	45	44	42	42	40	44	41	41	42	49
	47	49	40	44	48	44	41	46	46	50
Conlan.....	76	67	63	63	57	59	50	56	55	51
	67	67	62	60	56	56	56	58	53	53
Squad III	*2/2*		*2/3*		*2/4*		*2/5*		*2/6*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Mantinband....	41	42	43	44	34	41	48	41	42	37
	42	43	40	51	44	46	40	39	40	38
Fisch.....	57	54	56	57	57	58	53	54	50	54
	59	53	65	57	64	61	60	61	55	69
Tanz.....	50	47	52	48	43	48	47	44	41	41
	51	47	48	50	44	51	47	46	42	39
Smith.....	61	58	55	51	59	54	53	48	56	49
	61	61	55	58	51	61	54	58	55	55
Squad IV	*2/9*		*2/10*		*2/11*		*2/12*		*2/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
O'Connell.....	66	58	59	59	59	56	57	55	51	52
	67	59	65	57	56	62	57	61	53	54
Kraus.....	53	48	45	50	40	46	50	50	42	48
	46	45	44	48	49	47	42	47	43	51
Godnick.....	53	47	45	48	42	41	49	47	44	45
	41	48	47	46	40	46	46	46	44	44
Ennis.....	45	41	38	38	37	36	34	39	38	40
	41	42	41	39	38	39	37	39	37	39
Squad V	*2/16*		*2/17*		*2/18*		*2/19*		*2/20*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Strumpf.....	47	47	54	49	42	49	47	48	46	46
	50	52	53	49	51	47	49	54	44	45
Schatz.....	45	45	42	41	42	39	41	42	42	39
	45	48	43	45	41	43	38	38	39	43
Deutsch.....	45	41	40	44	39	42	36	40	43	39
	44	42	39	41	39	42	38	41	38	39
Margolin.....	54	49	50	55	48	47	52	50	46	48
	51	55	47	50	46	48	50	48	49	49

TABLE 7

Cancellation of 2's and 3's: PRODUCT PRODUCED ON EACH SUCCESSIVE DAY BY NINETEEN INDIVIDUALS

In every case the upper row is for 2's and the lower row for 3's

Squad I	*12/15*		*12/16*		*12/17*		*12/18*		*12/19*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Grossberg.....	98	104	97	94	122	144	116	114	120	114
	102	101	102	114	110	116	109	116	110	112
Hanson.....	102	88	103	112	122	104	122	120	114	118
	96	103	111	102	112	108	106	122	112	107
Schachter.....	76	82	100	90	114	104	112	101	116	116
	82	92	98	94	110	110	114	112	114	110
Fried.....	94	94	108	108	108	107	110	113	116	118
	98	97	110	106	112	114	116	107	122	116
Squad II	*1/26*		*1/27*		*1/28*		*1/29*		*1/30*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Schroeder.....	90	100	98	96	96	98	95	90	102	90
	76	79	96	95	97	92	98	91	98	95
Frey.....	67	57	78	78	74	78	82	82	75	84
	76	72	76	72	82	75	80	82	82	82
Conlan.....	76	72	78	78	82	90	83	90	84	94
	72	82	82	82	92	88	88	84	84	84
Squad III	*2/2*		*2/3*		*2/4*		*2/5*		*2/6*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Mantenband....	62	80	74	100	100	98	110	114	102	106
	78	78	82	96	98	102	102	104	104	110
Fisch.....	84	78	82	90	88	90	92	90	98	90
	90	92	92	98	96	106	98	108	98	110
Tanz.....	78	78	80	84	80	92	110	96	100	110
	80	72	88	90	94	98	98	100	96	102
Smith.....	94	96	100	94	116	116	108	116	102	114
	100	102	100	102	110	106	110	102	108	120
Squad IV	*2/9*		*2/10*		*2/11*		*2/12*		*2/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
O'Connell.....	75	74	70	74	82	72	74	82	84	80
	68	78	86	76	76	76	78	76	76	78
Kraus.....	98	96	102	90	108	110	119	112	112	118
	102	88	102	106	112	110	116	112	118	118
Godnick.....	96	104	102	124	124	140	128	112	120	116
	106	100	106	98	110	124	122	128	112	126
Ennis.....	84	82	100	86	98	98	102	96	106	116
	88	96	96	108	100	98	104	110	114	118

TABLE 7—*Continued*

Squad V	2/16		2/17		2/18		2/19		2/20	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Strumpf	110	90	118	116	118	114	118	118	122	118
	104	98	114	100	114	110	107	108	124	116
Schatz	116	104	116	116	122	122	122	130	170	130
	112	100	116	116	122	124	126	130	134	120
Deutsch	82	90	96	122	104	106	114	114	120	118
	96	92	114	114	114	114	114	126	128	124
Margolin	92	104	116	108	118	116	128	128	132	138
	106	108	118	120	110	116	128	123	136	142

TABLE 8

Naming Opposites: TIME IN SECONDS TAKEN ON EACH SUCCESSIVE DAY BY THIRTY-NINE INDIVIDUALS

Each early and late period has two divisions. The upper row always represents the first division

Squad I	12/15		12/16		12/17		12/18		12/19	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Grossberg	101	94	57	67	53	48	48	44	39	37
	66	62	59	49	47	39	37	32	38	34
Hanson	105	125	78	79	65	55	54	55	47	48
	104	128	83	68	54	53	54	43	45	49
Schachter	116	76	51	59	51	52	46	42	51	49
	99	67	46	52	45	43	37	44	47	38
Fried	94	48	43	46	42	40	34	32	36	36
	53	45	44	44	33	31	28	31	31	27

Squad II	12/26		12/27		12/28		12/29		12/30	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Schroeder	89	72	69	60	59	55	54	61	55	55
	81	64	62	56	58	51	49	53	63	48
Frey	121	79	75	68	71	61	58	65	59	58
	76	81	65	69	66	57	59	52	54	54
Conlan	114	90	64	67	60	56	51	49	50	44
	92	94	55	55	48	48	47	51	42	43

Squad III	2/2		2/3		2/4		2/5		2/6	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Mantenband	78	60	49	47	37	42	36	46	42	37
	53	51	61	43	43	39	38	32	36	32
Fisch	61	56	50	42	40	63	41	38	37	35
	43	47	43	39	39	40	38	41	34	39
Tanz	105	80	60	56	52	55	53	56	48	47
	104	68	67	52	46	53	53	46	48	39
Smith	195	118	110	90	56	77	47	52	48	49
	121	115	74	75	70	59	50	47	38	43

TABLE 8—*Continued*

Squad IV	*2/9*		*2/10*		*2/11*		*2/12*		*2/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
O'Connell	104	80	67	66	66	64	58	60	46	50
	99	76	81	69	60	59	55	56	54	51
Kraus	109	65	48	55	51	42	44	41	46	40
	83	89	42	49	41	43	50	36	40	38
Godnick	87	63	43	39	41	41	35	32	33	30
	52	51	39	37	39	33	28	28	25	27
Ennis	77	59	51	46	46	38	36	41	36	34
	57	58	40	39	38	38	36	36	31	32
Squad V	*2/16*		*2/17*		*2/18*		*2/19*		*2/20*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Strumpf	65	54	50	47	40	37	44	39	39	38
	48	55	45	42	39	40	34	38	35	33
Schatz	73	63	75	56	50	49	41	43	37	37
	55	54	52	49	45	42	33	35	37	34
Deutsch	123	61	50	45	40	40	37	38	34	34
	90	56	45	39	36	36	33	32	35	31
Margolin	79	65	59	55	53	53	49	45	44	43
	51	55	50	54	47	46	41	41	46	39
Squad VI	*2/23*		*2/24*		*2/25*		*2/26*		*2/27*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Robinson	114	79	65	70	78	60	55	61	53	53
	111	67	63	67	49	61	61	50	45	51
Mendel	77	59	60	48	44	40	39	38	41	36
	74	50	46	53	43	37	33	39	38	38
Klein	143	98	68	68	66	55	50	61	55	48
	101	77	88	57	62	53	54	53	45	48
Doun	124	93	76	68	70	56	58	51	49	47
	78	63	72	65	55	52	42	44	37	38
Squad VII	*3/2*		*3/3*		*3/4*		*3/5*		*3/6*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Regard	127	75	51	61	41	49	39	40	38	41
	68	67	43	43	35	37	34	40	34	34
Nemser	152	94	94	98	75	71	80	75	74	66
	124	83	78	77	66	68	94	60	77	61
Smith	90	50	47	57	38	39	33	32	32	32
	58	45	52	38	40	34	30	30	29	29
Wallis	77	54	43	40	42	38	39	35	32	35
	75	44	41	39	35	39	32	35	29	33

TABLE 8—*Concluded*

Squad VIII	*3/9*		*3/10*		*3/11*		*3/12*		*3/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kummerl.....	96	102	62	74	75	65	50	60	53	50
	106	73	67	69	58	61	55	45	42	44
Kleinfeld.....	80	64	60	58	45	40	37	41	42	38
	60	50	55	48	49	38	42	36	36	35
Frankenstein....	100	72	60	59	45	45	55	45	41	42
	67	59	60	49	40	41	44	34	43	35
Brearman.....	144	94	56	61	48	45	44	40	42	49
	79	57	47	50	39	41	37	37	35	37

Squad IX	*3/17*		*3/18*		*3/19*		*3/20*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kramer.....	110	74	59	56	55	57	54	46
	82	60	57	51	57	47	41	40
Frankel.....	146	108	114	63	64	65	51	57
	110	78	65	57	59	53	50	49
Crowley.....	92	74	79	73	78	61	58	54
	83	70	60	66	71	66	55	55
Fullman.....	129	84	71	70	59	59	53	50
	113	58	62	53	48	46	54	47

Squad X	*3/23*		*3/24*		*3/25*		*3/26*		*3/27*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Farrell.....	129	79	74	54	52	45	44	41	45	42
	85	60	53	49	46	44	43	39	38	39
Lerner.....	84	57	48	56	52	49	41	43	36	38
	78	55	46	47	48	40	37	37	38	34
O'Connell.....	130	114	64	67	54	60	55	45	55	44
	101	99	63	62	48	56	59	43	42	41
Webber.....	115	117	89	107	77	57	58	55	51	46
	90	79	71	87	54	51	47	47	46	41

TABLE 9

Addition: PRODUCT PRODUCED ON SUCCESSIVE DAYS BY THIRTY-NINE INDIVIDUALS

Squad I	*12/15*		*12/16*		*12/17*		*12/18*		*12/19*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Grossberg.....	92	96	102	101	106	105	108	111	119	114
Hanson.....	72	72	74	72	64	69	75	81	75	85
Schachter.....	68	78	78	86	88	98	94	92	97	99
Fried.....	91	103	108	109	118	124	131	135	134	137

TABLE 9—*Continued*

Squad II	*12/26*		*12/27*		*12/28*		*12/29*		*12/30*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Schroder	47	46	45	48	50	51	48	55	53	55
Frey	39	40	48	46	50	52	57	56	57	56
Conlan	38	36	41	47	47	52	55	57	57	62

Squad III	*2/2*		*2/3*		*2/4*		*2/5*		*2/6*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Mantenband	68	69	75	73	82	83	86	89	105	100
Fisch	52	66	72	75	78	78	91	86	91	91
Tanz	54	58	69	62	60	69	68	73	80	72
Smith	68	58	53	64	60	62	68	65	60	74

Squad IV	*2/9*		*2/10*		*2/11*		*2/12*		*2/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
O'Connell	39	44	41	53	45	47	50	52	53	51
Kraus	45	44	48	47	55	60	62	63	64	66
Godnick	96	96	96	101	108	112	119	122	120	106
Ennis	55	54	58	65	63	57	57	69	78	74

Squad V	*2/16*		*2/17*		*2/18*		*2/19*		*2/20*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Strumpf	58	65	71	65	70	73	72	79	81	83
Schatz	62	61	69	69	77	75	79	80	81	81
Deutsch	90	93	103	107	104	104	116	117	118	119
Margolin	64	69	85	78	84	84	94	91	86	98

Squad VI	*2/23*		*2/24*		*2/25*		*2/26*		*2/27*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Robinson	33	33	42	35	44	47	52	53	52	48
Mendel	53	54	52	53	56	59	65	67	59	77
Klein	35	35	42	41	48	50	54	59	47	55
Doun	61	67	67	65	66	70	64	82	85	90

Squad VII	*3/2*		*3/3*		*3/4*		*3/5*		*3/6*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Regard	91	92	93	101	105	100	113	113	113	115
Nemser	35	35	37	36	36	41	45	42	47	49
Smith	44	47	49	51	45	42	51	46	53	62
Wallis	81	87	95	98	107	102	106	105	105	105

Squad VIII	*3/9*		*3/10*		*3/11*		*3/12*		*3/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kummerl	40	56	55	69	72	65	69	80	75	81
Kleinfeld	72	74	83	86	95	98	104	102	107	111
Frankenstein	75	73	74	76	82	98	95	94	93	96
Brearman	60	63	65	62	74	75	82	85	88	89

TABLE 9—*Concluded*

Squad IX	*3/17*		*3/18*		*3/19*		*3/20*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kramer	44	48	50	55	52	55	62	56
Frankel	66	66	69	61	73	73	74	79
Crowley	37	37	41	35	44	44	34	42
Fullman	37	41	44	46	48	40	54	50

Squad X	*3/23*		*3/24*		*3/25*		*3/26*		*3/27*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Farrell	53	55	64	63	67	77	69	75	77	76
Lerner	59	60	60	65	65	70	71	72	77	82
O'Connor	39	65	61	66	73	76	73	74	94	88
Webber	103	102	111	110	99	104	105	105	119	116

TABLE 10

Mental Multiplication: PRODUCT PRODUCED ON SUCCESSIVE DAYS BY THIRTY-NINE INDIVIDUALS

Squad I	*12/15*		*12/16*		*12/17*		*12/18*		*12/19*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Grossberg	20	28	38	45	52	46	58	60	66	65
Hanson	13	17	15	21	44	26	40	20	30	25
Schachter	35	47	41	60	71	68	79	58	77	88
Fried	42	36	45	45	61	54	60	63	65	70

Squad II	*12/26*		*12/27*		*12/28*		*12/29*		*12/30*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Schroder	28	31	19	38	24	42	14	45	55	67
Frey	40	56	38	55	74	60	80	75	78	84
Conlan	40	37	39	49	50	48	50	41	56	70

Squad III	*2/2*		*2/3*		*2/4*		*2/5*		*2/6*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Mantenband	49	52	72	71	85	74	70	80	78	102
Fisch	9	36	33	34	50	52	61	66	59	66
Tanz	50	74	84	79	92	105	86	107	98	118
Smith	70	70	85	90	74	92	100	106	116	162

Squad IV	*2/9*		*2/10*		*2/11*		*2/12*		*2/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
O'Connell	33	33	39	31	46	36	42	45	36	43
Kraus	34	37	39	46	45	44	65	55	50	52
Godnick	Spurious results; used business "catch."									
Ennis	53	65	62	78	74	78	69	87	78	87

Squad V	*2/16*		*2/17*		*2/18*		*2/19*		*2/20*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Strumpf	26	59	69	98	83	81	88	102	86	90
Schatz	44	44	64	71	75	95	96	105	96	105
Deutsch	40	38	44	43	54	39	47	3	58	47
Margolin	27	50	47	57	69	77	66	78	78	88

TABLE 10—*Continued*

Squad VI	*2/23*		*2/24*		*2/25*		*2/26*		*2/27*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Robinson	20	16	25	21	35	29	35	39	37	33
Mendel	19	25	16	25	28	29	25	33	37	38
Klein	35	21	38	30	37	36	50	35	42	41
Doun	32	39	52	55	52	44	43	56	57	50

Squad VII	*3/2*		*3/3*		*3/4*		*3/5*		*3/6*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Regard	41	49	46	44	58	54	75	67	53	58
Nemser	25	22	68	72	101	122	129	168	164	160
Smith	38	75	83	83	107	91	108	126	123	124
Wallis	44	46	51	45	72	76	81	90	95	95

Squad VIII	*3/9*		*3/10*		*3/11*		*3/12*		*3/13*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kummerl	10	13	33	45	35	30	42	48	52	49
Fleinfeld	30	47	49	47	53	52	41	57	40	49
Frankenstein	47	76	69	67	65	68	79	88	73	70
Brearman	24	31	34	40	44	48	51	56	61	55

Squad IX	*3/17*		*3/18*		*3/19*		*3/20*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kramer	23	38	38	42	46	48	57	52
Frankel	33	36	34	58	68	64	60	83
Crowley	34	55	66	86	78	87	154	101
Fullman	16	23	15	16	19	32	32	44

Squad X	*3/23*		*3/24*		*3/25*		*3/26*		*3/27*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Farrell	41	50	60	51	70	54	76	89	84	73
Lerner	30	32	45	59	58	79	77	93	96	79
O'Connor	38	45	45	46	48	53	52	70	77	72
Webber	31	12	18	30	28	29	28	42	28	42

TABLE 11

Typewriting: PRODUCT PRODUCED ON SUCCESSIVE DAYS BY TWENTY INDIVIDUALS

Squad VI	*2/23*		*2/24*		*2/25*		*2/26*		*2/27*	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Robinson	127	141	142	141	156	165	175	157	171	172
Mendel	27	43	48	49	63	60	56	56	68	69
Klein	128	143	141	144	159	159	173	168	*	161
Doun	47	52	53	66	56	75	76	70	93	89

* typewriter broke.

TABLE 11—*Continued*

Squad VII	3/2		3/3		3/4		3/5		3/6	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Regard	28	35	64	58	53	71	68	79	75	70
Nemser	76	71	78	82	83	91	86	93	93	94
Smith	73	79	84	102	92	96	104	102	106	108
Wallis	72	67	77	70	88	69	81	79	84	76

Squad VIII	3/9		3/10		3/11		3/12		3/13	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kummerl	159	151	152	156	108	168	187	171	185	194
Kleinfeld	42	34	47	45	63	47	57	53	72	67
Frankenstein	44	63	48	51	56	59	60	73	73	76
Brearman	50	61	47	54	51	55	66	62	75	70

Squad IX	3/17		3/18		3/19		3/20	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Kramer	48	48	49	53	59	57	67	38
Frankel	65	74	60	67	81	75	78	69
Crowley	79	75	68	65	94	89	89	73
Fullman	37	31	34	53	41	49	50	38

Squad X	3/23		3/24		3/25		3/26		3/27	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Farrell	144	130	141	147	149	164	161	142	170	174
Lerner	83	89	80	93	84	105	107	100	107	109
O'Connor	103	108	102	111	96	108	127	125	105	134
Webber	42	40	57	58	65	55	58	62	54	67

TABLE 12

Physical Condition: THE REPORT ON SUCCESSIVE DAYS OF THIRTY-NINE SUBJECTS AS TO THEIR PHYSICAL COMFORT

Squad I	12/15	12/16	12/17	12/18	12/19
Grossberg	2	4	4	3	5
Hanson	2	2	3	2	5
Schachter	2	4	4	3	5
Fried	4	4	4	5	5

Squad II	12/26	12/27	12/28	12/29	12/30
Schroder	4	4	3	3	2
Frey	4	3	2	3	2
Conlan	4	4	2	3	3

Squad III	2/2	2/3	2/4	2/5	2/6
Mantenband	4	3	5	3	3
Fisch	3	4	4	3	3
Tanz	3	4	4	2	4
Smith	3	2	5	4	3

TABLE 12—*Continued*

Squad IV	*2/9*	*2/10*	*2/11*	*2/12*	*2/13*
O'Connell	4	4	4	4	4
Kraus	5	4	4	4	5
Godnick	4	4	4	4	4
Ennis	3	3	4	4	3
Squad V	*2/16*	*2/17*	*2/18*	*2/19*	*2/20*
Strumpf	4	3	4	3	5
Schatz	4	3	4	3	5
Deutsch	4	4	4	3	4
Margolin	4	4	4	3	4
Squad VI	*2/23*	*2/24*	*2/25*	*2/26*	*2/27*
Robinson	3	3	4	3	4
Mendel	2	3	3	4	4
Klein	3	3	3	4	4
Doun	1	1	3	4	4
Squad VII	*3/2*	*3/3*	*3/4*	*3/5*	*3/6*
Regard	4	4	3	3	3
Nemser	4	4	4	4	4
Smith	4	2	4	4	1
Wallis	3	4	4	4	2
Squad VIII	*3/9*	*3/10*	*3/11*	*3/12*	*3/13*
Kummerl	1	4	4	4	4
Kleinfeld	2	4	4	3	4
Frankenstein	3	4	4	3	2
Brearman	3	4	4	3	3
Squad IX	*3/17*	*3/18*	*3/19*	*3/20*	
Kramer	3	2	4	4	
Frankel	3	3	4	4	
Crowley	3	2	5	4	
Fullman	3	3	3	4	
Squad X	*3/23*	*3/24*	*3/25*	*3/26*	*3/27*
Farrell	4	3	3	3	3
Lerner	4	4	4	4	3
O'Connor	2	4	3	4	3
Webber	3	3	3	4	3

EXPERIMENT II

THE EFFECT OF CONDITIONS OF THE AIR UPON THE RATE OF IMPROVEMENT OF MENTAL FUNCTIONS

By E. L. THORNDIKE AND W. A. McCALL*

The results reported by Dr. Chapman (pp. 1 to 23) for the experiments with daily change of air conditions show that when a person exerts himself, his achievement at mental work is as good under various bad conditions, up to "No fans, recirculated air-supply, 86° F., 80% relative humidity," as under the best conditions (45 cu. ft. of outside air per person per minute, 68° F., 50% relative humidity).

The results of the experiment now to be reported show that the same holds true as between the worst and best conditions, when each is maintained for four hours daily during five successive days, and that the improvement made during the work of a "bad condition" week is equal to the improvement made during a "best condition" week.

The two conditions mentioned above were contrasted in the case of 15 subjects, college students, each of whom was subjected to one five-day period with the bad and one five-day period with the good condition. Eight had the good week first, the bad week immediately following. Seven had the bad week first, the good week immediately following. The time was four hours in each case, though only about two hours were given up to the mental work, the balance being required for the physiological measurements that were made.

The physical conditions in the experimental room were maintained only approximately as stated above, because the working of the plant required recirculation at times to maintain the high tempera-

* The first author is responsible for the plan of the experiments, the preparation of the material, the statistical treatment of the results and the report here made. The second author is responsible for the administration and scoring of the experiments, and concurs in the conclusions of the report here made. The maintenance of the physical conditions for these experiments was as in the series reported by Dr. Chapman.

ture and humidity, and because of other minor difficulties. In view of the general result of the experiments (which was negative), these minor irregularities are of no importance so far as concerns the psychological problem investigated. The room conditions during the experiments were as shown in Table 13.

The instructions and all other conditions, save those of the air, were as nearly identical for all the fifteen as Mr. McCall, who conducted all these experiments, could make them. The details of the administration and scoring of these experiments were the same as those reported by Dr. Chapman. The scores to be reported here are thus measures of the quantity and quality of the product produced, representing a fair combination of the individual's speed and accuracy in the number-checking, addition, mental-multiplication, and typewriting which were the forms of work done.

First, we may compare the gross total efficiency of the work under the bad and the good conditions. The facts are shown in Table 14.

The product produced (with allowance for its quality) under the bad condition is thus 97 per cent of that produced under the good condition in the case of checking numbers; 106 per cent in the case of addition; 102 per cent in the case of the very difficult mental multiplication; and 102 per cent in the case of typewriting.

The result of the "one-day-four-hour" tests of Experiment I (that mental efficiency at maximal exertion is unimpaired by the bad air condition) is thus fully corroborated by these more elaborate experiments. They also show that the bad condition was as favorable as the good, not only to temporary efficiency but also to improvement from practice. For there was, with all subjects, great improvement during the ten days; consequently, had the good air condition been more favorable to this learning process, its effect must have appeared in the quantity and quality of the total product produced during the good air condition compared with that produced during the bad air condition.

There might conceivably have been certain subtle compensating conditions masking an effect of the air on human ability to improve. There was no such effect, however. A full analysis of the actual course of improvement from day to day under each condition shows that any differences in the rate of improvement are probably accidental and are surely as much in favor of the bad condition as of the good. We present this analysis in the form, first, of curves showing the efficiency of each of the functions or tasks at each successive period, and, second, of tables repeating the facts numerically.

TABLE 13

RECORDED ROOM CONDITIONS DURING EXPERIMENT II

		1	2	3	4	5	6	7	8	9	10
		Motion of air	*Nature of air supply*	*Humidity*	*Temperature*	*Air supply*	*Cu. ft. per person per minute*	*Humidity*	*Temperature*	*CO_2 parts per 10,000 at beginning of period*	*CO_2 parts per 10,000 at end of period*
SQUAD I	March 30	2	4	2	2	Fresh	37	51	68.0		
	31		"			"	37	48	68.5		
	April 1		"			"	37	52	67.5		
	2		"			"	44	46	67.5		
	3		"			"	42	50	68.0		
										4.0	5.0
	April 6	2	Recirc.	3	3	Recirc.	39	76	86.5		
	7		"			"	39	72	87		
	8		"			"	39	79	86		
	9		"			"	39	78	86		
	10		"			"	39	79	85.5		
										5.0	6.9
SQUAD III	April 13	2	Recirc.	3	3	Recirc.	39	71	86.5		
	14		"			"	49	78	86		
	15		"			"	39	78	86		
	16		"			"	39	81	85.5		
	17		"			"	39	79	86		
										3.8	7.8
	April 20	2	4	2	2	Fresh	45	58	69.5		
	21		"			"	46	47	68		
	22		"			"	46	53	69		
	23		"			"	45	48	70		
	24		"			"	44	48	69		
										3.5	5.2
SQUAD II	May 4	2	4	2	2	Fresh	43	48	69		
	5		"			"	44	61	67.5		
	6		"			"	45	50	68		
	7		"			"	44	52	67		
	8		"			"	44	56	67.5		
										4.2	5.7
	May 11	2	Recirc.	3	3	Recirc.	39	76	88.5	5.5	7.0
	12	2	Recirc.	3	3	Recirc.	39	77	84		
	13	1	1	3	3	No sup.	0	81	86.5	6.2	25.0
	14	1	1	3	3	"	0	74	87		
	15	1	1	3	3	"	0	81	86.5		

TABLE 13—*Continued*

		1	2	3	4	5	6	7	8	9	10
		Motion of air	*Nature of air supply*	*Humidity*	*Temperature*	*Air supply*	*Cu. ft. per person per minute*	*Humidity*	*Temperature*	*CO_2 parts per 10,000 at beginning of period*	*CO_2 parts per 10,000 at end of period*
SQUAD IV	May 18	1	1	3	3	No. sup	0	81	86		
	19		"			"	0	81	85.5		
	20		"			"	0	81	86		
	21		"			"	0	81	85.5		
	22		"			"	0	80.5	86.5		
										6.1	38.3
	May 25	2	4	2	2	Fresh	33	52	68.5		
	26		"			"	45	52	68		
	27		"			"	45	54	67.5		
	28		"			"	45	49	68		
	29		"			"	45	50	68		
										4.6	5.2

Columns 1 to 4 show the standards which on each day the operator tried to maintain.

In column 1, under "motion of air,"
1=no movement save what the subject and experimenter caused.
2=no movement save what the subject and experimenter caused and also that caused by the ingress of air at the rate shown in column 6.

In column 2, under "nature of air supply,"
1=no outside air supplied, or practically none.
recirc=recirculation at the rate shown. There was leakage as shown by CO_2.
4=45 cu. ft. per person per minute approximately; see column 6.

In column 3, under "humidity,"
2=50% relative humidity.
3=80% " "

In column 4, under "temperature,"
2=68° F.
3=86° F.

Columns 5–10 show the recorded room conditions. Columns 9 and 10 are averages for the weeks or fractions of weeks in question.

TABLE 14

GROSS TOTAL EFFICIENCY

	Under good condition. 45 cu. ft., 68°, 50%	Under bad condition No fans, no air-supply, 86°, 80%
2's cancelled (with allowance for errors)	22,853	21,411
3's cancelled (with allowance for errors)	21,931	21,909
Columns added (with allowance for errors)	12,788	13,518
3-place numbers multiplied mentally (with allowance for errors)	17,152	17,564
Amount typewritten (with allowance for errors)	46,604	47,447

Consider first Fig. 1, which tells the story of the average efficiency in successive days in checking 2's, of the eight subjects who had the "good condition" week first, by the height of the continuous line; and the same story for the average of the seven who had the "bad condition" week first, by the height of the dash line. The reader should examine this diagram and its explanation with some

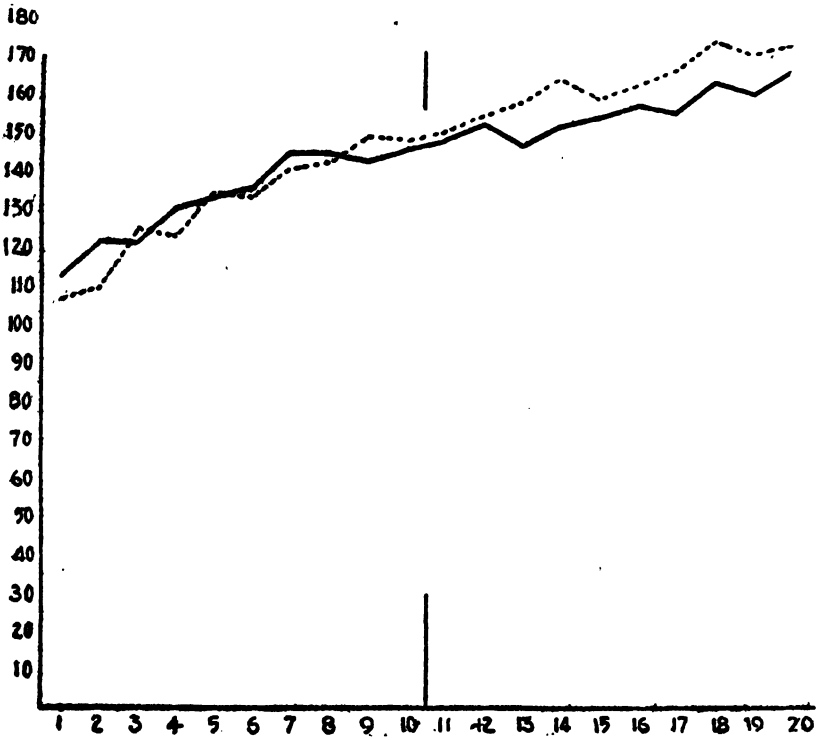

FIG. 1

care as all those to follow are drawn after the same plan. Lengths along the base-line represent amounts of practice, each two successive divisions representing one successive day of the experiment or 120 seconds of work. The height of the curve represents the efficiency of the work. There are thus two points for each of the ten days, two tests of 60 seconds each having been made daily. If the good air condition had been the more favorable to improvement, the continuous line should mount rapidly during the first half of its course

and then much more slowly; while the dash-line curve should mount slowly during the first half of its course and then much more rapidly, as shown roughly in Fig. 2. As a matter of fact the continuous line does not rise quite so rapidly during the first half as does the dash-line representing the average of those then under the bad condition. During the second half, when the group scored by the continuous line were under the bad condition, their gain is a little less than that

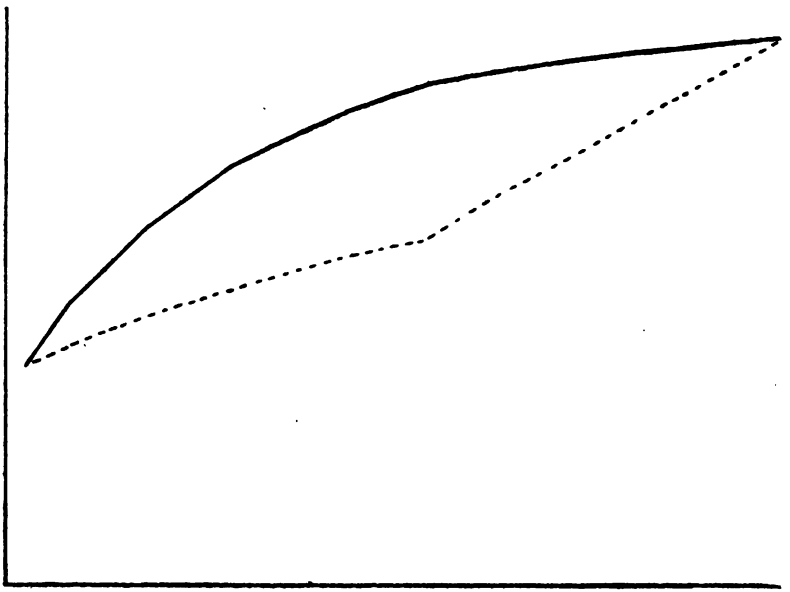

FIG. 2

of the contrasted group, but the inferiority of their gain is no greater than it was when they had the good air condition. As a whole, then, the differences between the two curves are explainable by the simple fact that the "bad-condition-first" group made on the average more gain in cancelling 2's than did the "good-condition-first" group. They did so as much under one condition as under the other. The effect of the air condition seems to be absolutely *nil*. There are ups and downs such as are always found in mental work, and these variations from day to day, or from period to period of

a day,* are large, showing that the function in question is susceptible enough to *some* conditions. But the air condition shows no effect.

Fig. 3 shows similar facts for checking 3's. The course of improvement bears no positive relation to the air-conditions. The dash-line group, which had the bad air condition for the first half of the curve, gained more than the other group did in its first half, and

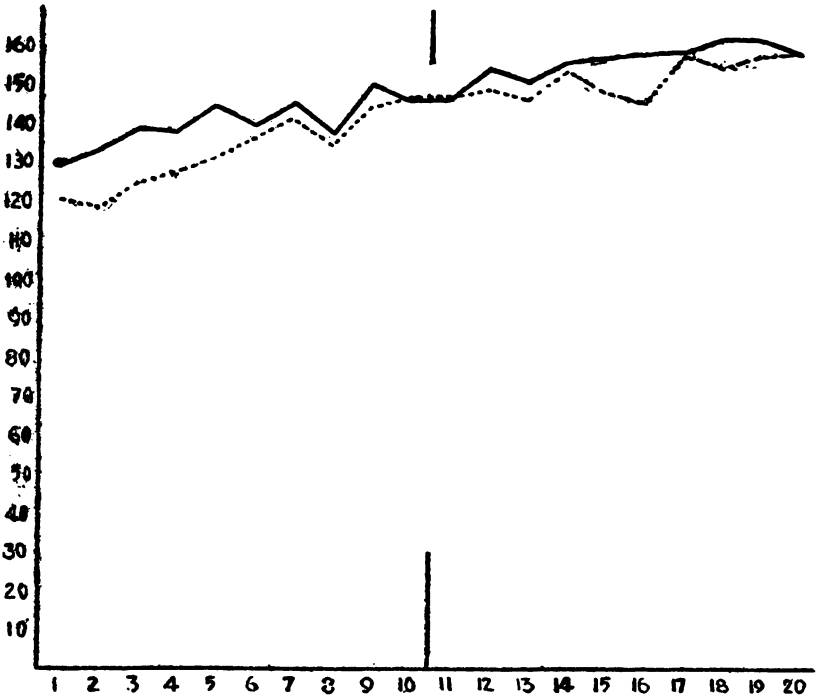

FIG. 3

did not gain any more than the other group when conditions were reversed. So, if the facts are taken at their face value, the bad condition seems somewhat *more* favorable to improvement. This, how-

* The curves do not show the same *chronological* day at the same points, since the tests were made in four separate series with squads of four subjects per series. The same point on the continuous line is due to an average from two days that were two weeks apart, and the corresponding point on the dash line is due to an average from two still different days. The variations of any one chronological day from another for any one subject are far greater than the variations in the curves. How great they are will appear from the tables to be shown later.

ever, is probably a chance result due to the small number of subjects, as will appear later.

Fig. 4 shows similar facts for addition. Here there is a considerable balance in favor of the bad condition. The continuous-line group gains notably under the bad condition; while the dash-line group gains little under the good condition. In the first half of the course of practice when the continuous-line group was under the good condition, and the dash-line group was under the bad condition, the gains were indistinguishable.

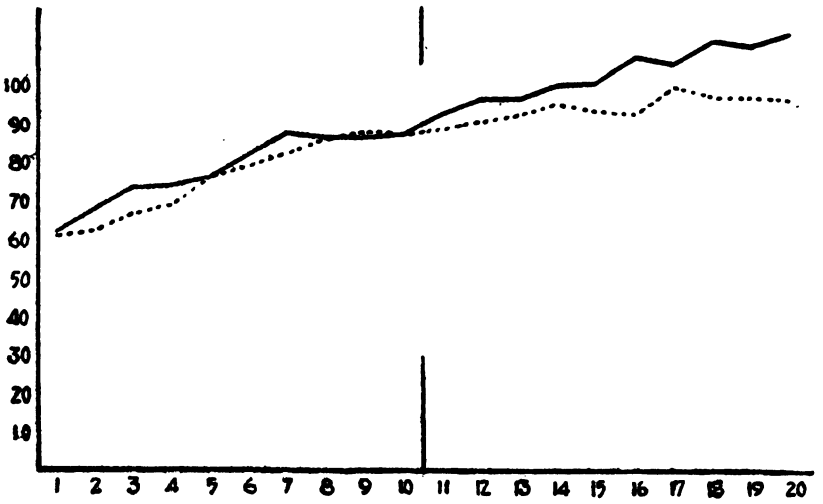

FIG. 4

Fig. 5 shows similar facts for the mental multiplication. Here there is a balance in favor of the good condition. In the first half of the curve, representing the good air condition for the continuous-line group and the bad air condition for the dash-line group, the continuous-line group made much greater gain. However, they maintain their lead during the second half when they work under the bad air condition and the dash-line group has the good condition. On the whole, the results with the mental multiplication about balance the opposite result with the addition.

Fig. 6 shows similar facts for the typewriting. The seven individuals who had the bad condition first (dash-line group) happened

to be on the average much better at typewriting than the eight who had the good condition first, so that the eye has a somewhat harder task in following the comparison of progress. But in general the two curves are almost alike. There is equal rapid gain in the first half of the practice whether the air condition is good (continuous

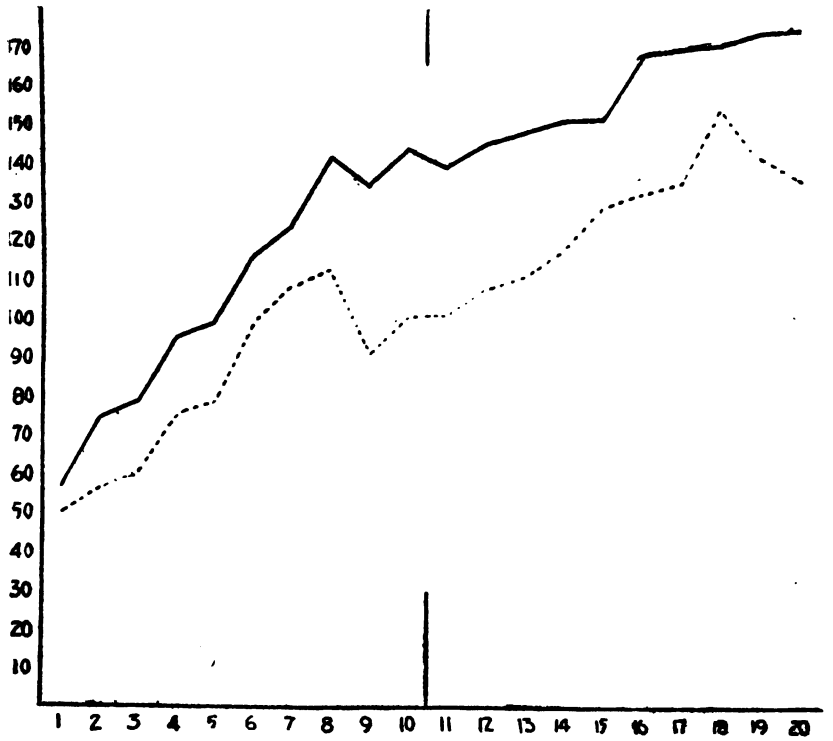

FIG. 5

line) or bad (dash line). There is equal, but much slower gain in the second half of the practice whether the air condition is good (dash line) or bad (continuous line). Neglecting the differences in absolute ability at typewriting and retaining only the gains by superimposing the two curves at their beginnings, we have Fig. 7.

The net total result is obviously that the air conditions used made no considerable difference in ability to work and to improve at the

tasks in question. Taking the results at their face-value, there is a very, very slight advantage in favor of the bad condition.*

The facts already shown in Figs. 1 to 7 are given with greater

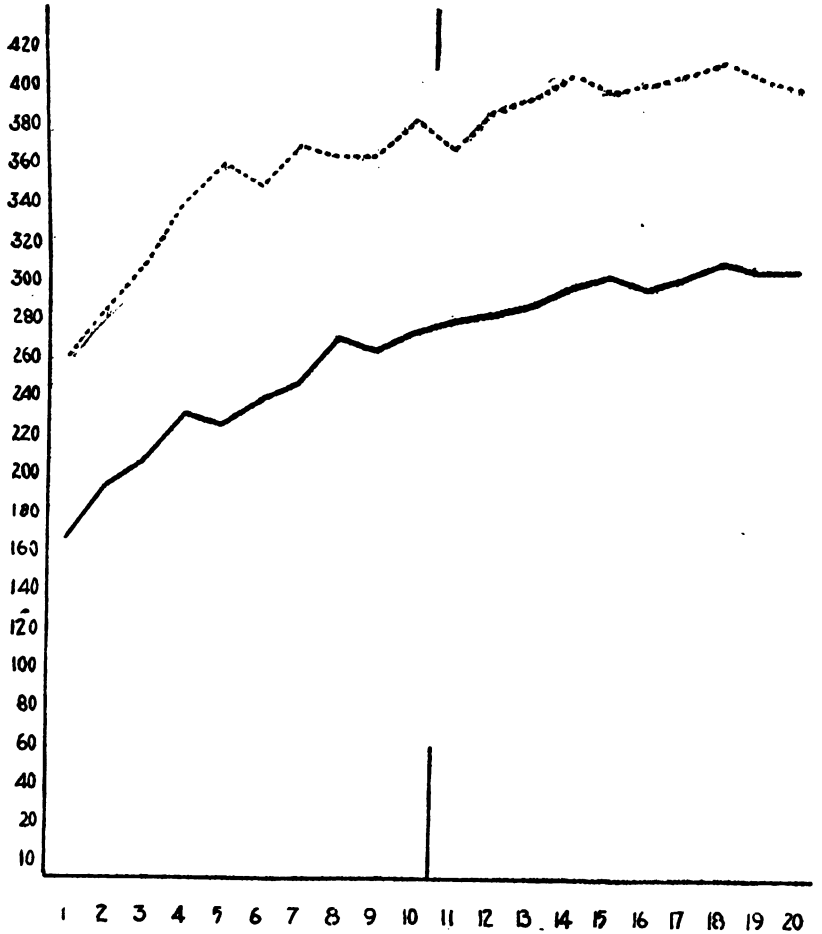

FIG. 6

detail and exactitude in Tables 15 to 19. These tables present the score for each individual in each function at each successive period.

* It may possibly be the case that the slight rise in body-temperature which accompanies the bad air condition may facilitate mental action, especially of the purely associational sort, such as addition.

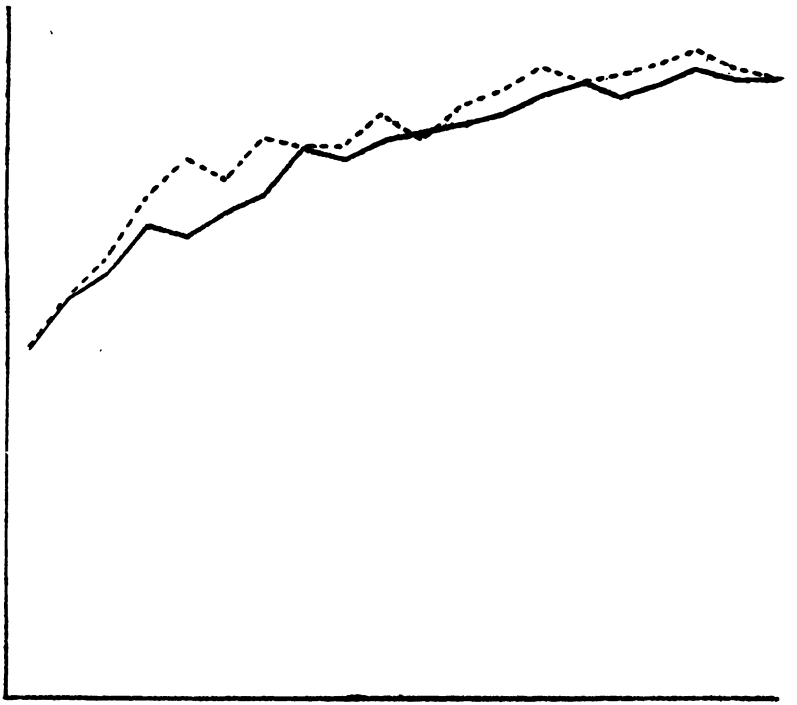

FIG. 7

Table 20 shows the condition of felt discomfort as reported by each subject at the close of each day of the experiment, using the rough scale whereby

5 = I feel as comfortable as I ever do, or nearly so.

3 = I feel about as I usually do at the close of an afternoon of hard mental work.

1 = I feel as uncomfortable as I would with a severe headache or an attack of the grippe.

4 = My condition is about half way between 3 and 5.

2 = My condition is about half way between 1 and 3.

TABLE 15

CANCELLING 2's. Product produced on each successive day by each of eight individuals, who worked under the good air condition for the first week, and under the bad condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Good Air Conditions: 45 cu. ft., 68, 50										*Bad Air Conditions: No Fans, no Supply, 86, 80*									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad I																				
Brod.	134	146	140	146	148	153	152	160	164	160	162	168	170	174	172	170	168	180	174	166
Feig	132	134	130	140	144	143	152	150	160	150	156	150	152	146	156	162	160	186	164	162
Leik	120	130	124	136	134	141	148	152	148	150	152	154	154	144	142	154	148	156	154	156
Levy	94	110	128	118	122	120	142	134	138	126	138	134	130	140	134	140	140	130	136	154
Squad II																				
Kuen	110	112	114	124	140	124	142	132	130	134	138	144	134	136	136	142	144	144	152	158
Rivl	118	122	114	136	140	146	146	146	150	160	156	162	154	170	178	180	160	190	184	188
Stac	88	106	106	114	114	126	124	122	104	122	128	138	124	142	138	150	144	162	154	166
Zuck	104	114	114	126	124	130	148	144	134	150	142	154	140	150	156	144	162	150	140	160
Average	112	122	121	130	133	135	144	143	141	144	146	147	151	145	150	152	153	162	157	164

TABLE 15 (*Continued*)

CANCELLING 2's. Product produced on each successive day by each of seven individuals, who worked under the bad air condition for the first week and under the good air condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Bad Air Conditions: No Fans, no Supply, 86, 80										*Good Air Conditions:* 45 *cu. ft.*, 68, 50									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad III																				
Bost	104	106	118	136	142	150	156	162	166	162	164	176	174	180	180	184	194	196	200	196
Elle	108	108	132	142	132	148	148	158	166	170	168	178	174	180	184	190	178	186	195	202
Solo	134	140	154	160	164	166	180	168	176	156	162	176	184	182	184	188	182	182	190	198
Squad IV																				
Furs	78	86	90	80	88	88	84	90	104	110	102	110	102	112	110	108	112	114	110	100
Gold	108	114	134	116	160	150	156	162	164	166	170	162	180	182	170	180	188	196	190	190
Levin	108	114	136	132	150	138	150	152	160	166	158	162	170	182	164	172	186	194	186	194
Zaja	100	92	110	98	100	92	104	96	98	100	112	106	112	120	104	96	106	126	102	112
Average	106	109	125	123	134	133	140	141	148	147	148	153	157	163	157	160	164	171	168	170

TABLE 16

CANCELLING 3's. Product produced on each successive day by each of eight individuals, who worked under the good air condition for the first week, and under the bad condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Good Air Conditions: 45 *cu. ft.*, 68, 50										*Bad Air Conditions: No Fans, no Supply*, 86, 80									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad I																				
Brod	150	152	158	162	163	162	164	170	168	170	170	180	176	180	180	182	182	186	186	176
Feig	132	132	146	148	143	142	148	150	150	146	146	162	156	158	156	160	160	162	158	162
Leik	142	138	150	144	152	151	158	160	160	164	162	164	166	170	170	168	168	170	180	156
Levy	98	124	136	130	129	132	133	136	154	140	142	144	136	130	130	131	136	152	148	142
Squad II																				
Kuen	122	126	122	132	132	126	130	108	126	128	132	136	124	132	134	136	136	132	138	142
Rivl	138	136	140	142	152	140	148	134	162	156	154	158	156	164	176	176	174	176	172	168
Stac	126	128	130	116	142	136	140	118	134	128	136	144	150	158	148	158	156	162	162	164
Zuck	122	126	132	132	144	132	148	130	150	146	134	150	154	162	166	164	158	164	160	152
Average	129	133	139	138	145	140	146	138	151	147	147	155	152	157	158	159	159	163	163	158

TABLE 16 (*Continued*)

CANCELLING 3's. Product produced on each successive day, by each of seven individuals, who worked under the bad air condition for the first week and under the good condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Bad Air Conditions: No Fans, no Supply, 86, 80										*Good Air Conditions:* 45 *cu. ft.*, 68, 50									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad III																				
Bost	124	124	124	132	144	138	150	158	162	166	158	170	162	176	174	172	168	176	176	176
Elle	108	118	108	104	94	130	130	132	130	144	134	132	148	144	150	140	155	134	143	166
Solo	144	150	162	172	160	158	180	174	162	170	170	172	164	184	174	170	180	176	196	182
Squad IV																				
Furs	90	92	100	102	116	120	120	96	128	124	126	128	124	128	120	124	132	126	128	128
Gold	130	118	130	136	144	152	154	154	164	160	168	166	158	168	156	164	178	176	168	170
Levin	120	132	128	132	144	148	138	138	150	152	158	148	154	160	150	152	174	174	168	164
Zaja	124	100	122	120	122	112	120	94	122	118	124	132	120	126	122	100	128	126	124	122
Average	120	119	125	128	132	137	142	135	145	148	148	150	147	155	149	146	159	155	158	158

TABLE 17

ADDITION. Product produced on each successive day by each of eight individuals, who worked under the good air condition for the first week and under the bad air condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Good Air Conditions: 45 *cu. ft.*, 68, 50										*Bad Air Conditions: No Fans, no Supply*, 86, 80									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad I																				
Brod.	94	113	120	113	111	119	129	128	118	128	129	130	133	131	142	150	148	157	151	149
Feig	62	79	74	69	75	79	90	94	88	93	101	105	104	105	108	122	119	122	122	131
Leik	63	69	75	78	77	80	82	93	94	62	97	98	86	93	88	97	90	108	95	99
Levy	40	44	43	43	47	46	54	53	57	47	59	64	63	67	61	67	65	68	60	70
Squad II																				
Kuen	53	50	68	68	73	79	82	79	81	89	85	88	94	94	90	97	93	107	97	108
Rivl	49	44	55	60	64	68	74	75	78	87	85	86	85	95	94	100	99	101	106	114
Stac	79	88	88	93	91	109	106	104	108	108	102	113	104	116	118	121	119	118	128	124
Zuck	53	59	67	67	67	76	77	79	85	81	79	80	95	99	102	104	105	107	113	110
Average	62	68	74	74	76	82	87	86	86	87	92	96	96	100	100	107	105	111	109	113

TABLE 17 (*Continued*)

ADDITION. Product produced on each successive day by each of seven individuals, who worked under the bad air condition for the first week, and under the good air condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Bad Air Conditions: No Fans, no Supply, 86, 80										*Good Air Conditions:* 45 *cu. ft.*, 68, 50									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad I																				
Bost	38	43	46	49	51	54	55	54	49	49	49	56	53	62	56	60	58	61	58	67
Elle	74	75	74	78	81	83	88	92	90	96	95	110	110	106	114	109	116	114	123	105
Solo	63	68	75	75	77	75	94	94	95	102	105	110	110	111	107	107	125	111	122	113
Squad II																				
Furs	71	70	74	82	84	87	95	91	100	91	96	82	91	105	95	90	100	96	84	86
Gold	63	60	69	56	93	92	91	106	111	100	109	104	111	113	113	112	115	112	111	103
Levin	64	68	73	85	92	101	96	105	102	107	103	106	106	109	106	108	116	112	121	118
Zaja	56	51	58	55	56	61	55	58	59	61	60	59	60	62	57	55	64	70	62	73
Average	61	62	67	69	76	79	82	86	87	87	88	90	92	95	93	92	99	97	97	95

TABLE 18

MENTAL MULTIPLICATION. Product produced on each successive day by each of eight individuals, who worked under the good air condition for the first week, and under the bad condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Good Air Conditions: 45 *cu. ft.*, 68, 50										*Bad Air Conditions: No Fans, no Supply*, 68, 80									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad I																				
Brod.	50	68	54	59	78	83	97	106	109	100	98	96	90	90	90	100	97	88	100	98
Feig	44	37	59	60	60	66	66	88	75	89	99	84	89	89	85	90	95	86	90	86
Leik	69	122	117	175	128	162	172	169	160	194	129	122	135	106	129	150	136	147	173	143
Levy	31	57	61	75	69	88	89	108	102	118	130	106	118	97	110	126	127	132	109	113
Squad II																				
Kuen	82	80	101	79	107	115	115	144	126	127	143	161	163	181	187	183	183	177	192	188
Rivl	40	47	25	63	67	83	96	149	127	128	132	149	164	175	167	187	189	208	179	200
Stac	65	82	90	96	116	139	159	170	149	170	159	189	174	196	182	203	214	199	218	212
Zuck	71	107	125	153	155	189	189	194	217	215	217	248	245	269	253	294	304	314	323	342
Average	57	75	79	95	98	116	123	141	133	143	138	144	147	150	150	167	168	169	173	173

TABLE 18 (*Continued*)

MENTAL MULTIPLICATION. Product produced on each successive day by each of seven individuals, who worked under the bad air condition for the first week and under the good air condition for the second week. *E* and *L* refer to early and late periods of the day's session.

	Bad Air Conditions: No Fans, no Supply, 86, 80										*Good Air Conditions:* 45 *cu. ft.*, 68, 50									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad III																				
Bost	68	96	88	124	117	128	163	180	147	189	175	202	198	200	208	237	235	271	282	279
Elle	67	80	92	119	99	128	119	151	135	164	176	169	194	184	213	201	221	254	226	250
Solo	89	113	90	119	104	125	112	125	124	136	124	142	143	147	150	154	157	142	161	164
Squad IV																				
Furs	54	50	57	65	73	99	115	126	107	74	84	88	80	106	109	104	98	143	96	82
Gold	37	27	29	31	64	94	110	65	52	65	69	70	75	90	122	127	126	146	103	64
Levin	23	18	32	34	31	31	30	40	38	43	47	43	50	55	59	58	59	75	67	50
Zaja	10	10	32	39	60	83	107	119	29	32	28	37	32	36	37	35	41	38	50	48
Average	50	56	60	76	78	98	108	112	90	100	100	107	110	117	128	131	134	153	141	134

TABLE 19

TYPEWRITING. Product produced on each successive day by each of eight individuals, who worked under the good condition for the first week, and under the bad condition for the second week. *E* and *L* refer to the early and late periods of the day's session. Each early and late period included two divisions which are scored here separately. The upper number is for the first division in every case.

	Good Air Conditions: 45 *cu. ft.*, 68, 50										*Bad Air Conditions: No Fans, no Supply*, 86, 80									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad I																				
Brod.	155	166	168	170	172	187	194	199	181	211	180	206	207	210	210	225	207	228	222	205
	132	158	136	209	163	192	195	232	192	197	204	236	193	191	217	221	227	237	219	183
Feig	61	77	92	108	84	110	105	134	98	132	121	136	144	117	149	132	134	133	141	144
	78	82	79	116	99	107	112	122	124	120	126	133	129	136	140	131	163	145	133	151
Leik	80	89	93	106	98	110	117	106	111	135	126	117	134	146	142	145	146	145	150	141
	80	95	94	103	103	116	108	141	127	132	130	133	129	123	141	137	152	143	153	145
Levy	71	86	87	83	93	104	110	127	111	122	123	121	136	129	132	124	129	145	141	124
	77	92	82	96	98	109	107	118	124	129	134	123	133	125	140	130	127	126	145	135
Squad II																				
Kuen	76	86	101	109	110	102	117	132	127	127	133	137	123	157	131	138	125	140	139	133
	85	80	110	113	96	117	128	126	129	130	138	129	135	141	130	128	130	150	126	137
Rivl	95	118	121	116	133	128	138	144	143	143	168	147	143	169	175	145	141	164	155	161
	101	123	130	130	146	136	130	154	131	149	156	127	174	175	165	168	173	163	153	174
Stac	39	53	76	81	80	97	92	108	101	100	104	117	111	148	130	128	123	134	125	147
	50	66	79	89	93	80	92	94	103	109	120	128	133	138	128	120	131	128	125	145
Zuck	84	86	104	107	119	109	122	115	126	132	130	128	131	143	140	153	156	151	162	169
	71	85	101	103	121	111	119	118	104	127	143	136	146	136	150	152	158	154	160	165
Average	167	193	207	230	226	239	248	271	266	274	280	282	288	298	303	297	303	311	306	307

TABLE 19 (*Continued*)

TYPEWRITING. Product produced on each successive day by each of seven individuals, who worked under the bad conditions for the first week, and under the good condition for the second week. *E* and *L* refer to early and late periods of the day's session. Each early and late period included two divisions which are scored here separately. The upper number is for the first division in every case.

	Bad Air Conditions: No Fans, no Supply, 86, 80										*Good Air Conditions:* 45 *cu. ft.*, 68, 50									
	1		2		3		4		5		6		7		8		9		10	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
Squad III																				
Bost.	120	147	148	161	177	175	191	185	153	217	203	203	204	218	221	216	234	187	240	237
	128	139	167	185	198	146	179	190	196	190	180	205	227	203	215	192	239	191	220	206
Elle	205	189	225	219	215	225	224	226	212	245	239	235	237	247	239	229	229	225	242	230
	198	191	210	229	164	212	212	209	223	207	223	236	236	239	231	255	246	256	223	229
Solo	59	114	127	131	140	123	121	138	139	153	130	139	139	163	156	157	152	177	170	160
	104	130	145	146	147	140	150	148	129	149	153	147	154	152	185	174	179	181	177	195
Squad IV																				
Furs	173	166	196	204	221	239	201	233	222	216	231	226	258	260	240	214	272	240	244	236
	194	177	180	204	230	215	225	247	220	222	209	233	237	251	209	248	258	245	227	211
Gold	203	212	207	227	245	261	242	274	252	262	263	261	244	272	258	261	248	260	250	258
	176	203	217	259	242	260	255	252	262	264	243	256	251	264	269	293	280	277	231	253
Levin	70	88	103	113	128	111	131	144	143	157	156	162	141	184	170	187	178	195	188	158
	68	84	73	119	123	132	130	132	125	147	135	169	173	174	163	172	184	188	165	179
Zaja	51	78	87	95	105	109	102	115	124	137	130	133	124	115	121	122	130	126	139	125
	63	76	79	95	89	106	106	119	157	122	130	120	139	112	115	129	137	140	117	124
Average	259	285	309	341	361	349	370	365	365	384	369	389	396	408	399	403	409	413	405	400

TABLE 20

REPORTS OF DISCOMFORT BY EACH SUBJECT AT THE CLOSE OF EACH DAY'S SESSION

	Good Air Condition					*Bad Air Condition*				
	1	2	3	4	5	6	7	8	9	10
Squad I										
Brod.....	4	4	4	4	3	3	2	2	2	2
Feig.....	4	4	4	5	4	3	3	3	4	3
Leik.....	4	4	4	4	5	3	3	3	3	3
Levy.....	4	4	4	5	5	3	3	4	4	5
Squad II										
Kuen.....	5	4	5	4	5	5	5	5	4	5
Rivl.....	4	4	4	4	4	3	4	4	4	4
Stac.....	4	2	5	4	4	4	4	3	4	4
Zuck.....	4	4	4	4	4	4	4	4	4	4
Average.....	4.1	3.75	4.25	4.25	4.25	3.5	3.5	3.5	3.6	3.75

	Bad Air Condition					*Good Air Condition*				
	1	2	3	4	5	6	7	8	9	10
Squad III										
Bost.....	4	2	4	4	2	5	5	5	5	5
Elle.....	5	5	5	5	5	5	5	5	5	5
Solo.....	4	4	3	4	3	5	5	5	5	5
Squad IV										
Furs.....	5	4	4	4	4	5	5	4	5	5
Gold.....	3	3	2	4	4	5	5	4	5	1
Levin.....	4	4	4	4	4	1	4	4	4	4
Zaja.....	2	3	4	3	3	4	4	3	4	4
Average.....	3.9	3.6	3.7	4.0	3.6	4.3	4.7	4.3	4.7	4.1

EXPERIMENT III

THE EFFECT OF CONDITIONS OF THE AIR UPON THE ACCURACY OF JUDGMENT

By W. A. McCALL AND E. L. THORNDIKE

In Experiments I and II, the subjects worked, presumably, with something approaching maximal effort, the incentives being their fixed daily wage, the instructions of the experimenter, and competition among themselves. Not only did they have a general notion of how well they were doing in each test, but each day they were given the scores made on the previous day.

The purpose of the experiment to be described was to ascertain the effect of conditions of the air upon mental work when the instructions of the experimenter, the conduct of the experiment, and the nature of the tests were such as not to stimulate effort but to encourage carelessness.

The tests were made upon four young men (students) who occupied the experimental room for six consecutive weeks, five days to the week and seven hours to the day. Six air variables were employed, each air condition lasting one week. They were:

1st week	— 68° F.	50%	r. h.	45 cu. ft.	No fans
2d "	— 86° F.	80%	" "	No air	" "
3d "	— 68° F.	50%	" "	No air	" "
4th "	— 86° F.	80%	" "	45 cu. ft.	" "
5th "	— 75° F.	50%	" "	45 cu. ft.	" "
6th "	— 86° F.	80%	" "	No air	5 "

The schedule for each week was:

For Mondays, Tuesdays, and Wednesdays

9:00–10:00 a. m. Physiological tests
10:00–12:00 a. m. Psychological tests
12:00– 1:00 p. m. Lunch served in the experimental room
1:00– 3:00 p. m. Psychological tests
3:00– 4:00 p. m. Physiological tests

For Thursdays and Fridays

9:00–12:00 and 1:00–4:00 Physiological tests

In the psychological tests, the subjects were asked to assign values to certain intellectual products. These intellectual products were specimens of handwriting and composition. The specimens of handwriting and composition had a quality range of from very nearly the worst to very nearly the best. About 10:00 a. m. each subject was provided with 110 specimens of penmanship and was asked to assign to each specimen a value according to the Thorndike Scale for Grading Handwriting. Following this he was asked to do likewise for 20 specimens of composition according to the Hillegas Scale for Grading English Composition. Before the six weeks of the experiment itself, the subjects were given preliminary practice in the form of judgment required and in the use of the scales.

The above constituted the work from 10:00–12:00 a. m. In the afternoon, the program was exactly the same. The experimenter was provided with 1320 specimens of penmanship and 240 specimens of composition. There were so many specimens and they were rotated in such a fashion that it was impossible for the subject to remember the values previously assigned.

It is evident from the nature of the tests employed that no subject could tell at any one moment just how well he was doing. Also, the work was intentionally made drearily monotonous and barren of interest. No scores were given throughout the entire test. The subjects were never urged to accuracy. Their names even were never known to the experimenter. Each man had a symbol. Carelessness and laziness were enhanced by giving them twice the time necessary to complete the assigned task. They could cease work at any moment and go to sleep if they wished, provided the assignment was completed by the end of the period. During the two-hour psychological test no general conversation and no comparison of grades were permitted. The experimenter did record the time taken by each individual for each section of the test. He also made observations upon the general reactions of the subjects to the work and to the air condition. This was done in such an unobtrusive way that it resulted in little or no stimulating effect.

The purpose of the experiment, it has been said, was to measure the subjects' accuracy of judgment under various conditions of ventilation. In order that this might be done it was necessary to determine the true value of each specimen graded by the subjects. Given this, the accuracy of each judgment could be measured by finding its divergence from the true value. Of the 1320 specimens

of penmanship 1200 were carefully graded by 21 competent judges and the median of these 21 judgments was taken as the true value. In order to make sure that 21 judgments were sufficient to give an adequately reliable standard, the other 120 specimens of penmanship were graded by nearly 100 judges. The subjects' judgments on these 120 specimens were scored and are reported separately. The similarity of the average error for the 120 specimens and for the 1200 specimens certifies to the reliability of the standards derived from the 21 judgments. The English composition standards were the medians of the judgments of about 20 individuals. These individuals were the most competent of the graduate students specializing in English in Teachers College, New York City. In order to measure the reliability of these standards, about half of the 240 specimens of English composition were graded by many more judges. This resulted in some cases in a very, very slight displacement of the previously obtained standards. In each case the scales used by the subjects were used in standardizing the penmanship and composition.

The recorded physical conditions maintained during the course of the experiment are shown in Table 21. It will be observed that in this experiment there was no recirculation at all. Either an abundant supply of outside air was introduced or the room was left as completely sealed as possible. High CO_2 percentages were obtained. This was not the case in Experiment I, and was the case for only part of the time in Experiment II.

Using the penmanship and composition standards previously mentioned, the error made by each subject in his judgment of each specimen of penmanship and composition was measured. The average error for each subject for each half-day was calculated. Continuing the combination, the average error for all four subjects for the three days during which they were subjected to any one condition was found. This average error is the efficiency measure for that condition. The smaller the error, the greater the accuracy of the judgments. The measures in Tables 22, 23, and 24 give results for the six air conditions for the functions studied for the time indicated.

If an error curve were drawn according to the daily averages of the four subjects and this curve were smoothed out, the result would be very nearly a straight line. This means that no allowance need be made for practice. If the function improved, the improvement was offset by an increased boredom and consequent carelessness.

TABLE 21

RECORDED ROOM CONDITIONS DURING EXPERIMENT III

	1	2	3	4	5		6		
Date	Fans	Air Supply	Cu. ft. per person per min.	Humidity	Temperature		CO_2 parts per 10,000 *Beg.*	*Mid.*	*End*
6/8	No	F	45	63	68				6.5
6/9	"	F	45	51	68		5.5	6	
6/10	"	F	45	57	70		6	4.5	5
6/11	"	F	45	57	67		6	4.5	5
6/12	"	F	45	62	68		6	6	
						9:00	*11:30*	*2:00*	*3:30*
6/15	"	None	0	76	86	19		31	
6/16	"	"	0	79	86.5	4.5	30.5		29
6/17	"	"	0	71	87	10	8.5		29.5
6/18	"	"	0	81	85	9.5	21	29	17.5
6/19	"	"	0	82	86	11.5	31	36.5	29
6/22	"	"	0	54	69.5	8.5	31	40.5	44
6/23	"	"	0	50	67.5		25	39.5	32.5
6/24	"	"	0	51	67	15.5	23.5	31	32
6/25	"	"	0	54	66.5	11	57	54	54.5
6/26	"	"	0	52	67.5	15.5	42	51	47
6/29	"	F	45	70	84		12	6.5	6
6/30	"	F	45	79	86	7.5	7	8.5	5
7/1	"	F	45	80	86.5	5.5	6	5	4
7/2	"	F	45	80	86.5	5.5	10.5	5	
7/3	"	Experiment omitted							
7/6	"	F	45	54	74	6	5.5	9	7
7/7	"	F	45	56	75	4.5	8		9
7/8	"	F	45	63	75	7	18	6.5	6
7/9	"	F	45	68	81	8	17.5	8.5	7
7/10	"	F	45	66	81	5	21	7.5	7
7/13	"	F	0	76	91.5				19
7/14	"	F	0	79	90	4	11	19	19
7/15	"	F	0	80	87.5	5	18	15	20
7/16	"	F	0	74	86	7	35	29.5	33
7/17	"	F	0	81	85.5	3.5	32	34.5	30

A glance at the average errors shows that this mental function of judging the value of intellectual products was a highly variable function. It varied, but it varied irrespective of the air conditions.

An individual may make very much larger errors at one period than at another, but the hot, humid, stagnant periods show no larger errors than the cool, fresh periods. There is no demonstrable effect of heat or CO_2 content. Tables 22, 23, and 24 may be taken at their face value; for the amount of the errors varies irrespective of the speed of the judgments or their time location in the six weeks.

These tables then show that, in a very variable and sensitive function, the quality of the judgments is as good when the air is 86° as when it is 68° or 75°; when the outside air supply was reduced to as near zero as possible as when 45 cu. ft. per person per minute was possible. Further analysis shows that there is no demonstrable difference between the quality of the judgments early in the day and later which can be attributed to effect of heat or CO_2 content.

TABLE 22

LONG SERIES HANDWRITING. AVERAGE DEVIATION

	68° F., 50%, 45 cu. ft. no fans						*86° F., 80%, no fresh air, no fans*					
	6/19		6/10		6/11		6/15		6/16		6/17	
	*E**	*L**	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	1.71	1.99	1.15	1.33	1.26	1.10	.62	.78	.66	.64	.64	.57
E.M.J.	1.23	2.02	2.52	1.62	1.98	1.57	1.29	1.89	2.29	1.54	2.07	2.49
J.S.	.85	1.06	1.23	1.30	1.33	1.43	1.63	1.14	.93	.83	1.13	1.00
J.U.	.79	.74	1.03	1.25	.95	1.64	1.15	1.68	1.31	1.74	1.96	2.10
Total	4.58	5.81	5.93	5.50	5.52	5.74	4.69	5.49	5.19	4.75	5.80	6.16
By days	10.39		11.43		12.26		10.15		9.94		11.96	
By weeks			33.08						32.05			
Average			1.38						1.34			

Condition:	*68° F., 50%, no fresh air, no fans*						*86° F. 80%, 45 cu. ft. no fans*					
	6/22		6/23		6/24		6/29		6/30		7/1	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	0.68	0.93	0.58	0.67	0.59	0.55	0.61	0.49	0.57	0.46	0.62	0.52
E.M.J.	2.70	2.42	2.61	2.31	1.97	1.84	2.31	2.07	1.97	1.90	1.90	1.99
J.S.	0.81	0.85	0.88	1.00			1.18	1.24	1.03	0.97	1.14	1.06
J.U.	2.13	1.89	1.72	2.09	1.92	1.67	1.59	1.90	1.77	1.76	1.88	1.90
Total	6.32	6.09	5.79	6.07	4.48	4.06	5.69	5.70	5.34	5.09	5.54	5.47
By days	12.41		11.86		8.54		11.39		10.43		11.01	
By weeks			32.81						32.83			
Average			1.49						1.37			

Condition:	*75° F., 50%, 45 cu. ft. no fans*						*86° F., 80% no fresh air, 5 fans*					
	7/6		7/7		7/8		7/13		7/14		7/15	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	0.60	0.58	0.61	0.62	0.61	0.48	0.56	0.50	0.61	0.56	0.58	0.53
E.M.J.	2.23	1.84	1.82	1.72	1.78	1.67	1.65	1.47	1.51	1.89	1.50	1.54
J.S.	1.09	1.35	1.55	1.32	1.33	1.24	1.88	1.54	1.29	1.09	1.13	1.40
J.U.	1.92	1.96	1.92	2.08	1.33	1.61	1.36	1.55	1.68	2.13	1.86	1.73
Total	5.84	5.73	5.90	5.74	5.05	5.00	5.45	5.06	5.09	5.67	5.07	5.20
By days	11.57		11.64		10.05		10.51		10.76		10.27	
By weeks			33.26						31.54			
Average			1.39						1.31			

*E and L refer respectively to early and late periods of the same day.

TABLE 23

SHORT SERIES HANDWRITING. AVERAGE DEVIATION

Condition: *68° F., 50%, 45 cu. ft. no fans* *86° F., 80%, no fresh air, no fans*

	6/9		6/10		6/11		6/15		6/16		6/17	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	2.26	1.98	1.65	1.33	1.29	.98	1.38	1.44	.88	1.23	.53	.96
E.M.J.	1.46	1.13	1.34	1.44	1.35	1.01	1.14	.88	.82	1.47	1.62	1.33
J.S.	1.72	1.02	1.46	.64	.67	.94	1.79	1.42	1.57	1.27	.71	.92
J.U.	1.21	.83	.85	1.55	1.03	1.41	1.29	2.12	.87	1.35	1.90	2.03
Total	6.65	4.96	5.30	4.96	4.34	4.34	5.60	5.86	4.14	5.32	4.76	5.24
By days	11.61		10.26		8.68		11.46		9.46		10.00	
By weeks			30.55						30.92			
Average			1.27						1.29			

Condition: *68° F. 50%, no fresh air, no fans* *86° F. 80%, 45 cu. ft. no fans*

	6/22		6/23		6/24		6/29		6/30		7/1	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	1.28	1.45	1.26	.88	.89	.65	.78	.69	.89	.60	.99	1.02
E.M.J.	1.40	1.09	1.59	1.78	.79	1.16	1.09	.88	1.20	1.47	1.42	1.31
J.S.	1.16	0.82	.99	.89			1.75	.88	1.36	1.11	1.36	1.06
J.U.	1.60	1.29	1.33	1.71	1.42	1.26	1.29	1.72	1.23	1.10	1.22	2.07
Total	5.44	4.65	5.17	5.26	3.10	3.07	4.91	4.17	4.68	4.28	4.99	5.46
By days	10.09		10.43		6.17		9.08		8.96		10.45	
By weeks			26.69						28.49			
Average			1.22						1.18			

Condition: *75° F., 50%, 45 cu. ft. no fans* *86° F., 80% no fresh air, 5 fans*

	7/6		7/7		7/8		7/13		7/14		7/15	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	1.25	1.52	2.28	.69	.87	1.08	1.22	.58	.95	1.05	.90	.84
E.M.J.	1.16	.78	1.36	.79	.60	.84	1.05	.84	1.03	1.90	.98	2.08
J.S.	1.22	1.05	1.04	1.26	1.34	1.11	1.65	1.16	1.78	1.05	1.26	1.23
J.U.	1.48	1.50	1.46	1.66	1.16	1.61	1.51	1.57	1.51	1.20	1.07	1.07
Total	5.11	4.85	6.14	4.40	3.97	4.64	5.43	4.15	5.27	5.20	4.21	5.22
By days	9.96		10.54		8.61		9.58		10.47		9.43	
By weeks			29.11						29.48			
Average			1.21						1.22			

TABLE 24

COMPOSITION. AVERAGE DEVIATION

Condition: *68° F., 50%, 45 cu. ft., no fans* *86° F., 80%, no fresh air, no fans*

	6/9		6/10		6/11		6/15		6/16		6/17	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	12.4	8.6	14.2	6.7	6.65	6.45	7.35	9.26	9.2	9.25	7.15	6.45
E.M.J.	8.3	10.15	8.4	9.1	8.35	11.55	7.5	6.85	7.4	8.2	7.85	7.45
J.S.	8.7	7.65	7.8	7.25	11.1	7.65	10.7	6.95	9.7	7.1	11.45	7.4
J.U.	7.6	12.05	16.3	13.65	11.2	12.55	14.8	14.45	12.9	16.55	13.7	14.65
Total	37.0	38.45	46.7	36.7	37.3	38.2	40.35	37.51	39.2	41.1	40.15	35.95
By days	75.45		83.4		75.5		77.86		80.3		76.1	
By weeks			234.35						234.26			
Av. per half day			98						98			

Condition: *68° F., 50%, no fresh air, no fans* *86° F., 80%, 45 cu. ft., no fans*

	6/22		6/23		6/24		6/29		6/30		7/1	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	7.95	5.9	9.5	8.75	6.65	6.35	6.1	6.52	7.95	9.3	7.15	7.5
E.M.J.	5.7	6.8	8.55	6.3	5.25	9.65	7.6	8.45	8.8	10.05	9.2	8.95
J.S.	7.25	5.1	7.8	8.15			7.05	7.95	6.5	5.35	6.55	8.05
J.U.	10.15	13.55	14.5	12.95	9.3	11.75	10.85	8.4	8.85	10.15	14.3	11.85
Total	31.05	31.35	40.3	36.15	21.20	27.75	31.6	31.32	32.1	34.85	37.2	36.35
By days	62.4		76.5		58.95		62.92		66.95		73.55	
By weeks			197.85						203.42			
Average			8.9						8.5			

Condition: *75° F., 50%, 45 cu. ft., no fans* *86° F., 80%, no fresh air, no fans*

	7/6		7/7		7/8		7/13		7/14		7/15	
	E	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*	*E*	*L*
B.R.B.	7.95	6.6	8.4	8.15	7.35	7.45	6.15	7.31	7.9	7.3	7.05	7.2
E.M.J.	8.95	6.9	8.2	7.95	8.75	11.0	9.2	14.94	9.05	10.35	7.7	10.75
J.S.	5.65	8.25	6.25	7.35	8.7	5.25	7.5	5.85	6.55	4.7	8.15	7.15
J.U.	9.05	13.85	18.0	12.95	14.65	13.25	20.85	9.9	10.45	12.52	13.25	9.4
Total	31.6	35.6	40.85	36.4	39.45	36.95	43.7	38.0	33.95	34.87	36.15	34.5
By days	67.2		77.25		76.4		81.7		68.82		70.65	
By weeks			220.85						221.17			
Av. per half day			9.2						9.2			

The original plan for Experiment III did not contemplate making any use of the time spent in the judgments. Enough time was allotted to enable each person to examine the specimens carefully and to make his judgments as well as his ability allowed, any tendencies to relax care and effort being permitted to show themselves.

The time spent was, however, recorded, the detailed facts being given in Tables 25, 26, and 27. These tables show, besides the expected general decrease in time spent as the experiment progressed, an apparent tendency for the hot weeks to show a little more time spent than would be expected from their chronological position in the six-weeks series, and for the cool weeks to show a little less.

Table 28 and Fig. 8 summarize the facts. The time spent in making certain judgments of lines of poetry is included. The accuracy of these judgments has not yet been computed.*

What the significance is of a greater expenditure of time in such an experiment is not known. It might mean a real need of more time to make as good a judgment, or a stronger impulse to rest between judgments. It might mean a greater punctiliousness, spending more time than was needed. It might mean a change of attitude and habit due to matters entirely irrelevant to the conditions of the air in the room.

The judgments of comfort taken at the end of the day were as shown in Table 29. It appears, as in Experiment I, that the wet-bulb temperature was the main cause of discomfort, rather than any conditions of the air due to its chemical constitution.

It also appears that the comfort vote is in some measure a result of contrast effects. The votes late in the seven-hour period on the hot days report slightly greater comfort than do the votes early. The reverse is the case for the cool days (this was for June when the room at 68 was, as a rule, cooler than the outside air). The votes under the hot condition reported slightly greater comfort on the last day of the three than on the first. The reverse is the case for the cool weeks. Also the difference between comfort votes at

* While this monograph was in press, the accuracy of one-half of these judgments of poetry was computed. The subjects did a little better on the cool days. They also fell off during the day less on the cool days. The inclusion of this test's results with those of the tests in judging penmanship and composition, balances the slight advantage to the hot days which the latter showed. Giving about equal weight to each of the three and combining the average for the hot days differs from that of the cool days by less than one-half of one per cent.

TABLE 25

LONG SERIES HANDWRITING

Number of minutes taken by each of four individuals to rate 100 specimens of penmanship

68° F., 50% rel. hum., 45 cu. ft. no fans

	6/9		6/10		6/11	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	53	33	18	18	12	08
E. M. J.	65	39	40	33	22	14
J. S.	56	37	39	37	26	30
J. U.	55	38	31	32	21	16

86° F., 80% rel. hum., no air, no fans

	6/15		6/16		6/17	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	14	19	27	17	16	33
E. M. J.	15	24	21	19	15	28
J. S.	22	30	23	22	19	36
J. U.	29	38	34	36	12	19

68° F., 50% rel. hum., no air, no fans

	6/22		6/23		6/24	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	17	13	10	19	12	14
E. M. J.	16	13	14	14	12	19
J. S.	15	11	33	24		
J. U.	11	09	16	16	13	20

86° F., 80% rel. hum., 45 cu. ft. no fans

	6/29		6/30		7/1	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	13	10	08	22	20	24
E. M. J.	15	13	13	13	12	12
J. S.	14	12	13	10	17	26
J. U.	12	12	22	13	17	10

75° F., 50% rel. hum., 45 cu. ft. no fans

	7/6		7/7		7/8	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	12	13	12	12	21	21
E. M. J.	13	16	15	13	21	18
J. S.	12	29	14	29	18	22
J. U.	16	15	11	12	16	15

86° F., 80% rel. hum., no air, 5 fans

	7/13		7/14		7/15	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	29	27	21	21	13	26
E. M. J.	21	20	23	21	16	26
J. S.	31	17	46	20	16	26
J. U.	34	40	30	19	15	10

TABLE 26

SHORT SERIES HANDWRITING

Number of minutes taken by each of four individuals to rate 10 specimens of penmanship

68° F., 50% rel. hum., 45 cu. ft. no fans

	6/9		6/10		6/11	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	08	05	04	05	03	03
E. M. J.	05	12	07	09	04	03
J. S.	05	05	09	08	05	04
J. U.	05	06	05	05	04	03

86° F., 80% rel. hum., no air, no fans

	6/15		6/16		6/17	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	02	04	01	06	02	02
E. M. J.	03	04	03	06	07	04
J. S.	05	04	03	03	03	05
J. U.	05	03	02	02	04	02

68° F., 50% rel. hum., no air, no fans

	6/22		6/23		6/24	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	03	01	04	06	04	04
E. M. J.	05	03	09	03	04	04
J. S.	05	03	02	03		
J. U.	02	03	02	02	02	02

86° F., 80% rel. hum., 45 cu. ft. no fans

	6/29		6/30		7/1	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	02	02	02	01	03	03
E. M. J.	03	03	03	02	02	02
J. S.	03	03	03	01	03	03
J. U.	02	03	03	11	03	03

75° F., 50% rel. hum., 45 cu. ft. no fans

	7/6		7/7		7/8	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	02	02	03	03	08	03
E. M. J.	03	03	02	02	02	01
J. S.	06	03	04	03	02	01
J. U.	04	02	02	02	02	02

86° F., 80% rel. hum,. no air, 5 fans

	7/13		7/14		7/15	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	01	01	01	01	01	01
E. M. J.	02	03	03	02	02	02
J. S.	03	02	02	01	01	01
J. U.	02	04	03	02	02	01

TABLE 27

Composition

Number of minutes taken by each of four individuals to rate 20 specimens of composition

68° F., 50% rel. hum., 45 cu. ft. no fans

	6/9		6/10		6/11	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	38	25	37	31	18	23
E. M. J.	26	20	27	23	10	16
J. S.	25	22	27	25	22	15
J. U.	65	20	23	17	19	20

86° F., 80% rel. hum., no air, no fans

	6/15		6/16		6/17	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	11	13	14	16	13	13
E. M. J.	22	19	13	14	14	21
J. S.	23	18	19	23	20	31
J. U.	22	21	20	19	16	27

68° F., 50% rel. hum., no air, no fans

	6/22		6/23		6/24	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	15	16	15	20	18	18
E. M. J.	15	16	12	11	15	14
J. S.	19	14	19	18		
J. U.	11	10	12	13	12	14

86° F., 80% rel. hum., 45 cu. ft. no fans

	6/29		6/30		7/1	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	11	13	14	10	12	28
E. M. J.	11	10	09	07	10	09
J. S.	08	09	13	26	16	19
J. U.	11	14	15	13	18	12

75° F., 50% rel. hum., 45 cu. ft. no fans

	7/6		7/7		7/8	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	12	13	11	11	07	08
E. M. J.	07	09	05	04	07	09
J. S.	06	15	06	12	08	10
J. U.	09	08	08	07	09	08

86° F., 80% rel. hum., no air, 5 fans

	7/13		7/14		7/15	
	E	*L*	*E*	*L*	*E*	*L*
B. R. B.	13	13	10	13	11	09
E. M. J.	08	06	08	06	07	05
J. S.	13	12	15	08	07	07
J. U.	12	08	12	12	06	05

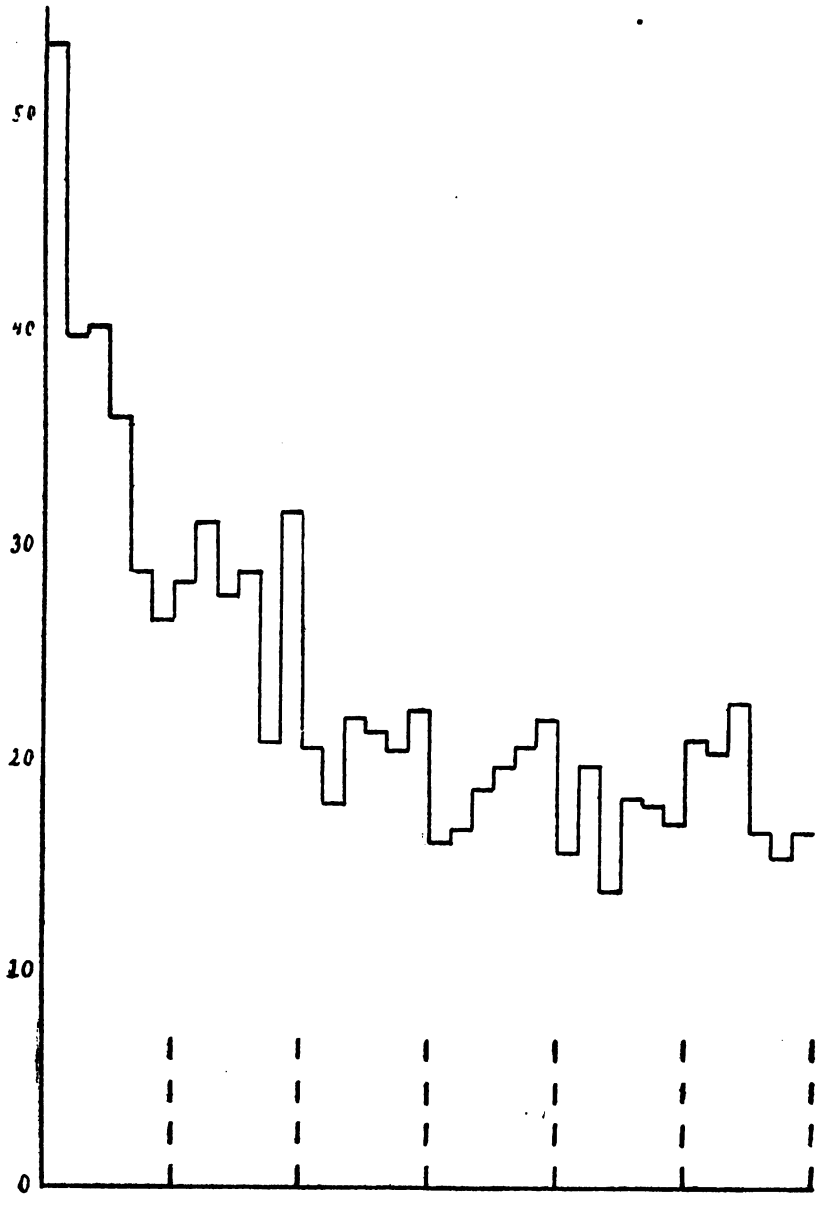

FIG. 8. Average Number of Minutes Spent in Examining and Judging in Each Period under each Condition of the Air. The vertical dash-lines mark the divisions between the weeks, the base-line representing the six weeks of the experiment in chronological order.

TABLE 28

TOTAL TIME SPENT BY FOUR SUBJECTS IN EXAMINING AND JUDGING SPECIMENS OF HANDWRITING, COMPOSITION, AND POETRY

68° F., 50% rel. hum., 45 cu. ft., no fans

6/9		6/10		6/11		First 3	Last 3
E	*L*	*E*	*L*	*E*	*L*		
533	397	401	360	288	266	1331	914

86° F., 80% rel. hum., no air, no fans

6/15		6/16		6/17			
E	*L*	*E*	*L*	*E*	*L*		
283	311	278	289	208	316	872	813

68° F., 50% rel. hum., no air, no fans

6/22		6/23		6/24			
E	*L*	*E*	*L*	*E*	*L*		
206	180	220	213	205	223	606	641

86° F., 80% rel. hum., 45 cu. ft., no fans

6/29		6/30		7/1			
E	*L*	*E*	*L*	*E*	*L*		
162	167	186	197	207	219	515	623

75° F., 50% rel. hum., 45 cu. ft., no fans

7/6		7/7		7/8			
E	*L*	*E*	*L*	*E*	*L*		
157	197	139	183	179	171	493	533

86° F., 80% rel. hum., no air, 5 fans

7/13		7/14		7/15			
E	*L*	*E*	*L*	*E*	*L*		
210	204	227	167	154	166	641	487

TABLE 29

COMFORT JUDGMENTS

Condition: *68° F., 50%, 45 cu. ft. no fans.* *86° F., 80%, no fresh air, no fans.*

	6/9		6/10		6/11		6/15		6/16		6/17	
	E	L	E	L	E	L	E	L	E	L	E	L
B. R. B....	4	4	4	5	5	4	3	3	3	4	3	4
E. M. J....	5	5	4	4	5	4	4	4	4	4	4	3
J. S.....	3	4	4	4	4	4	4	4	4	4	4	4
J. U.....	5	4	3	3	5	3	2	3	2	3	4	3
Total.....	17	17	15	16	19	15	13	14	13	15	15	14
Week total			99						84			
Average....			4.1						3.5			

TABLE 29—*Continued*

Condition: *68° F., 50%, no fresh air, no fans. 86° F., 80%, 45 cu. ft. no fans.*

	6/22		6/23		6/24		6/29		6/30		7/1	
	E	L	E	L	E	L	E	L	E	L	E	L
B. R. B....	4	3	5	5	5	4	4	3	4	3	3	3
E. M. J....	4	4	4	3	4	3	4	3	4	3	2	3
J. S.....	5	4	3	4			4	4	4	4	4	4
J. U.....	5	4	2	3	4	3	4	3	3	4	2	4
Total.....	18	15	14	15	13	10	16	13	15	14	11	14
Week total			85						83			
Average....			3.9						3.5			

Condition: *75° F., 50%, no fresh air, no fans. 86° F., 80%, no fresh air, 5 fans.*

	7/6		7/7		7/8		7/13		7/14		7/15	
	E	L	E	L	E	L	E	L	E	L	E	L
B. R. B....	4	4	4	4	4	4	2	3	3	3	3	3
E. M. J....	4	3	4	4	4	4	4	5	4	4	4	4
J. S.....	5	4	4	4	4	4	2	3	2	3	4	4
J. U.....	4	4	4	4	4	4	2	2	3	4	4	4
Total.....	17	15	16	16	16	16	10	13	12	14	15	15
Week total			96						79			
Average....			4.0						3.3			

TABLE 30

AVERAGE COMFORT VOTES FOR THE "WORST" AND "BEST" CONDITIONS OF THE AIR

	86 80 No air No fans	*86 80 Recirc. No fans*	*68 50 45 cu. ft.*	*Diff. in favor of the "good" condition*	
Exp. I a		2.5	3.6	1.1	Average for
" b		3.0	3.8	.8	daily change, 9.5
" II. a	3.57		4.12	.55	
" b	3.76		4.42	.66	Average for weekly change, .6
Exp. III	3.5		4.1	.6	

"86°, 80%, no air or recirculation" and those at "68°, 50%, 45 cu. ft." was greater in Experiment I when the subjects were under the conditions only for a day, than in Experiments II and III when the subjects were under the conditions for a week. This last relation is shown in Table 30.

THE EFFECT OF CERTAIN CONDITIONS OF THE AIR UPON THE CHOICE OF ALTERNATIVES TO MENTAL WORK

By W. A. McCALL AND E. L. THORNDIKE

General Conditions

It was shown by Dr. Chapman (pp. 1 to 23) that the effect of five air conditions ranging from "68° F. 50% relative humidity and 45 cu. ft. of air per person per minute" to "86° F. 80%, recirculated air and stagnant," upon the efficiency of certain mental functions was the same, when the young men tested were subjected to each of the five conditions for one day of five hours. Thorndike and McCall corroborated these results for the same mental functions by showing (pp. 24 to 45) that, even though the time during which the young men were subjected to any one condition be increased from one day of four hours to five consecutive days of four hours each, the difference between the best and the worst conditions, either in the gross total score or in the rate of improvement, was negligible. Such as it was, it slightly favored the worse condition.

In Experiments I and II the subjects were encouraged to work with maximal effort. Not only did they have a general notion of how well they were doing in each test, but each day they were given the scores made on the previous day. In Experiment III Thorndike and McCall found (pp. 46 to 59) the same lack of difference for the same range of air conditions including a hot, humid condition with a very high CO_2 percentage, for certain mental functions whose daily efficiency it was impossible for the subjects to know. There was, however, a possible effect of the hot, humid conditions in the direction of using 'more of the period for the work and less for rest,' or of using time for brief frequent intermissions in the course of the work rather than for one long intermission at the close.

The present experiments (VI and VIII) were designed to measure the effect of various conditions of the air upon the quantity and quality of certain mental products, when the subjects were left to

their own choice as to how much work they should do. Two conditions of the air were contrasted: (a) 68° F., 50% rel. hum., no outside air, no fans, and (b) 75° F. 50% rel. hum., no outside air, no fans.

The experiment is divided into two sections. In the first section four young men were subjected to each of the two conditions for five consecutive days. From 9 a. m. until 12 m. the subjects were under the condition 68° F. 50%, no fresh air and stagnant. From 12 m. until 1 p. m. while lunch was served in the experimental room the condition was changed to 75° F. 50%, no fresh air and stagnant. This air condition was maintained from 1 p. m. until 4 p. m. when the subjects left the chamber. Four other subjects were also tested under the above conditions, the order of the conditions being reversed. For them the morning was 75° F., and the afternoon 68° F.

In the second section of the experiment four still different subjects worked under these two conditions six consecutive days instead of five, the first three days of seven hours each being "68° F. 50%, no fresh air and stagnant," and the last three "75° F. 50%, no fresh air and stagnant." Four others worked for a similar six days with the order of the conditions exactly reversed. In all other respects the two sections were identical.

All the subjects were young men. With a few exceptions, they were students in the College of the City of New York or in New York University. The only bases of selection were normal health and the ability to do three-place by three-place mental multiplication. The subjects wore uniforms provided by the Commission, the same uniforms being worn under all conditions.

The Tests

We shall call those tests "maximal effort" tests in which the subject is required to do his very best, and call those "option" tests in which the subject is requested to do as much or as little as he pleases.

Mental Multiplication Option

This was an option test. In the option tests certain alternatives were proposed. The subject was encouraged to feel absolutely free in choosing among the alternatives but under no circumstances was he permitted to make use of an option not allowed.

Mental Multiplication Option. In this test the options were: (a) mental multiplication of a three-place by a three-place number, (b) reading a current novel, (c) resting quietly, and (d) sleep. The test occurred once each half-day lasting for one hour and five minutes.

At any moment the subject could leave one of the options and take up another. The method of scoring the mental multiplication was as follows: a score of 10 for each problem done correctly, with 1 taken off for 1, 2 for 2, 3 for 3, and 5 for 4 wrong figures in the answer. No credit was given if more than four figures were wrong. The subject was paid a small bonus for doing the difficult mental multiplication. The amount of this bonus was determined by the formula:

$$\text{Bonus} = [\text{Gross score} - (2 \times \text{errors})]\ \$.001$$

This remuneration was selected as one suitable to balance the motives for doing mental multiplication and reading a novel.

Typewriting Option. The options in this test were (a) typewriting, (b) conversation, (c) doing nothing, and (d) sleep. Throughout the seven hours of the day no general conversation was permitted except during the noon hour and the period of this test. As in the mental multiplication test the subjects were free to elect any alternative and to drop it for another at will. This freedom was further guaranteed by the absence of the experimenter from the room. Occasionally the experimenter would look in through a small window to see that the proper options were being observed. No bonus was offered for typewriting. The only motive was an interest in learning to typewrite and in the manipulation of the machine. Competition was reduced by keeping the subjects ignorant of their exact scores. The score in typewriting was the number of lines correctly copied multiplied by ten, with one taken off for each wrong letter or wrong space. The typewriting test lasted an hour and five minutes and occurred once each half-day.

The schedule which follows shows the order of the tests and the time given to each:

8:45 a. m.	Report—Dress.
8:55	Enter experimental chamber.
9 – 9:10	Addition.
9:10	Body temperature.
9:20–10:25	Mental Multiplication Option Test.
10:30–11:35	Typewriting Option Test.
11:40–11:50	Addition.
11:50	Body temperature and lunch.
1:00 p. m.	Body temperature.
1:10– 1:20	Addition.
1:25– 2:30	Mental Multiplication Option Test.
2:35– 3:40	Typewriting Option Test.
3:45– 3:55	Addition.
3:55	Body temperature.
4:00	Leave experimental chamber.

At the end of each half-day the subjects were asked to hand in a secret ballot of their physical comfort, using the scale previously described (page 9).

Addition at Maximal Effort. The 10-minute test described on page 8 was given at the beginning and at the end of each half-day.

Details of Administration. On Friday preceding the Monday morning on which the new squad began work the subjects were put through a preliminary training. Printed instruction sheets such as are found at the end of this paper were placed in the hands of each subject. When these had been read, some practice was given in each of the tests. The amount of this practice is shown in the following schedule:

Addition. Ten minutes.

Mental Multiplication. Until not more than two wrong figures in the answer.

Typewriting. Until acquainted with the manipulation of the machine.

As already noted, the subjects were not given their scores in typewriting. In the other tests they were informed, before beginning each test, concerning the scores which they had made in the corresponding test on the previous day. At the close of this article are the instruction sheets with which the subjects were provided. A perusal of these will give the essential details of administration.

While the conditions maintained in the experimental chamber were not always absolutely correct, the divergences of the obtained from the desired conditions were with one exception so slight as to be negligible. The recorded room conditions are not printed here, but are available in the files of the New York State Commission on Ventilation. The one exception refers to the fact that, owing to a break-down in the operation of the plant, the tests were conducted for one half-day in an ordinary classroom. The condition in this room was so nearly the desired one that this irregularity would have no appreciable effect upon the total score.

Experiment VIII

The experiment just described was conducted during the month of October and will be referred to as Experiment VI. During the month of November Experiment VI was repeated on sixteen other subjects, all conditions being kept as nearly identical as the experimenter could make them. The duplicate of Experiment VI is numbered Experiment VIII. Sections I and II of Experiment VI correspond respectively to Sections I and II of Experiment VIII. If we

can disregard slight differences in the season of the year and unconscious variations in the conduct of the experiment, Experiments VI and VIII can be treated as one experiment.

Massing the results in this way, we find that when the temperature changed every half-day from 68° to 75°, the average scores were:

EXPERIMENTS VI AND VIII

	At 68°	At 75°
Addition at Maximal Effort	64.4	62.7
Mental Multiplication Option	143.3	146.6
Typewriting Option	256.8	192.6
Comfort Vote	4.0	4.1

When the temperature changed every three days, the average scores were:

	At 68°	At 75°
Addition at Maximal Effort	76.0	75.6
Mental Multiplication	117.1	138.9
Typewriting Option	351.4	377.1
Comfort Vote	4.3	4.2

So far as these measurements alone go, heat seems (a) to have, as in Experiments I and II, substantially no effect upon addition at one's best, (b) to lead to the choice of the very difficult mental multiplication over light reading, rest, or sleep, and (c) to lead to the choice of conversation, rest, or sleep over typewriting. The last occurs only when the 75° and 68° conditions are contrasted on the same day. The results for different individuals and squads in the case of the option tests are, however, far more variable than was the case in Experiments I and II.

Hence the numerical results shown above may best be combined with certain results from Experiment XIV, which was in general of the same purpose and nature as Experiments VI and VIII.

In Experiment XIV the average scores were, when the temperature changed every half-day:

	At 68°	At 75°
Mental Multiplication Option	147.7	139.6
Typewriting Option	289.5	267.3
Comfort Vote	4.8	4.6

When the temperature changed every three days, they were:

	At 68°	At 75°
Mental Multiplication Option	52.6	64.5
Typewriting Option	302.9	306.0
Comfort Vote	4.6	4.7

If we combine all these results (the weighting is such as to give equal weight to each individual) we have:

	Half-day change		*Three-day change*		*Both changes combined*	
	At 68°	At 75°	At 68°	At 75°	At 68°	At 75°
Men. Mult. Opt.	145.5	143.1	84.9	101.7	115.2	122.4
Typewrit. Opt.....	273.2	230.0	327.2	341.6	300.2	285.8

If we weight the two option tests equally (each occupied 65 minutes) and combine, we find the influence of 75° as compared with 68° upon the choice between the work in question and light reading, conversation, rest or sleep, to be *nil*. It may be noted here also that the general averages of the comfort votes were identical for the 68° and 75° conditions.

This general summary comes from a large body of very variable results from Experiments VI and VII already described, and Experiment XIV shortly to be described. It is possible to argue from these results that the 75° condition is favorable to the non-muscular mental multiplication and unfavorable to the more muscular work of typewriting. It is also possible to argue that such is the case, but only when a sharp contrast is afforded as by the half-day change. A purely statistical treatment of the measurements at their face value would slightly favor the last claim as against the simple hypothesis of zero effect. The detailed facts are given in Tables 31 to 41.

Experiment XIV

The conditions contrasted in this experiment were 68° F. 50% relative humidity, 30 cu. ft. of fresh air per person per minute with four electric fans at high speed, with 75° F. 50%, 30 cu. ft. and fans. The general plan for Section I of the experiment was to have a squad of four young women occupy the experimental chamber two weeks, five days to the week and seven hours to the day, with a fifteen-minute recess at noon and at the middle of the morning and afternoon sessions. The first week, during the morning, the condition was 68° F. 50%, 30 cu. ft. and fans. During the noon hour while lunch was being served in the experimental room the condition was changed to 75° F. 50%, 30 cu. ft. with fans, which was maintained the rest of the afternoon. The order of conditions was exactly reversed during the second week. Following these two weeks four other young women occupied the experimental room two weeks, with these two conditions everywhere reversed, the 75° condition coming in the mornings of the

first week and in the afternoons of the second. For Section II, four women occupied the room two weeks, five days to the week, seven hours to the day, with the usual recesses. The condition for the first week was 68° F. 50%, 30 cu. ft. with fans, and for the second week 75° F. 50%, 30 cu. ft. with fans. A squad of three others reversed the order of these conditions. The physical conditions were maintained satisfactorily. A record of them is not given here, but is available in the files of the New York State Commission on Ventilation.

The tests for both sections of Experiment XIV were the same. A description of them follows:

Cancellation of 2's and 3's for one minute each at maximal effort (see the description of these tests on page 7).

Mental Multiplication Option Test. The options in this test were: (a) the mental multiplication of a three-place by a two-place number, (b) reading interesting short stories and (c) resting quietly. The score in mental multiplication was 10 for every problem done correctly, with 2 taken off for each wrong figure. A small bonus was paid for doing mental multiplication, the amount of the bonus being determined by the following formula:

$$\text{Bonus} = (\text{Gross score} - 2 \times \text{errors})\ \$.001$$

Typewriting Option Test: This was identical with that described as a feature of Experiments VI and VII (see page 62).

Addition Option Test: The alternatives offered by this test were addition for a small bonus or idling. The bonus was calculated by the formula:

$$\text{Bonus} = \frac{(\text{Net Score})}{100}\ \$0.03$$

$$\text{Net Score} = \text{Columns added correctly.}$$

Mental Multiplication at Maximal Effort: A short test in finding the products, each of a three-place by a two-place number.

Addition at Maximal Effort: A test of five minutes length.

The following schedule gives the order of the tests and the time given to each:

HALF-DAY PROGRAM

8:45—Enter experimental chamber.
1 minute—Cancellation 2's (Maximal Effort).
1 minute—Cancellation 3's (Maximal Effort).
Two problems—Mental Multiplication (Maximal Effort).

HALF-DAY PROGRAM—*Continued*

30 minutes—Mental Multiplication or Options.
15 minutes—Recess.
40 minutes—Typewriting or options.
5 minutes—Addition (Maximal Effort).
20 minutes—Addition or option.
1 minute—Cancellation 2's (Maximal Effort).
1 minute—Cancellation 3's (Maximal Effort).
12 m.—Lunch and fifteen-minute recess.

The afternoon duplicated the morning schedule. As in previous experiments the subjects gave a comfort vote at the end of each half-day. In addition to the usual comfort vote, the women subjects were asked to give a temperature vote by the following scale:

50—Too hot.
40—Too warm.
30—Just right.
20—Too cool.
10—Too cold.

In the tables, the comfort vote and the temperature vote are given together, the first figure of the compound number being the comfort vote.

The total results from Experiment XIV in the case of the choice between work at mental multiplication and typewriting on the one hand, and reading, conversation, rest or sleep on the other, have been reported. In the case of the option between adding and idling the average scores when the temperature changed from 68° to 75° every half-day were: At 68°, 154.0; at 75°, 155.5. When the temperature changed every three days, the average scores were: At 68°, 123.1; at 75°, 123.3. There is the confirmation of the general result of zero effect obtained in the case of the other option tests.

The cancellation tests at maximal effort showed the same absence of effect found in Experiments I and II, the total averages being:

	At 68°	At 75°
For cancelling 2's.....	132.4	135.1
" " 3's.....	147.5	147.2

The average vote on temperature (28.3 for 68° and 35.8 for 75°) showed that in spite of similar reports on general well-being for the 68° condition and the 75° condition (4.7 and 4.7), the subjects were conscious of the greater heat and disapproved of it. They did so as much or more when the change was made every three days (28.5 and 37.3).

The short tests with multiplication and addition at maximal effort showed nothing different from the findings of Experiments I, II, VI, and VIII.

Detailed tables are given only for the option experiments. The facts for the maximal effort tests, and the votes on general well-being and the temperature of the room, are adequately represented by the averages already given or included in Table 41.

TABLE 31: EXPERIMENTS VI AND VIII

MENTAL MULTIPLICATION OPTION: PRODUCT PRODUCED ON SUCCESSIVE HALF-DAYS BY SIXTEEN INDIVIDUALS

Individual	*A. M. 68° P. M. 75°*									
	9/14		9/15		9/16		9/17		9/18	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
1	43	16	36	0	0	0	97	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	46	69	100	60	0	0	28	127	99	89
4	10	0	9	0	0	0	0	0	0	0
	11/23		11/24		11/25		11/27		11/28	
5	215	318	379	452	554	591	622	652	656	721
6	84	146	184	167	247	241	313	308	349	417
7	150	180	180	240	261	281	252	352	386	427
8	146	187	189	218	292	320	400	502	559	495
	A. M. 75° P. M. 68°									
	9/21		9/22		9/23		9/24		9/25	
9	92	139	134	140	190	190	259	307	287	227
10	25	45	80	95	105	89	135	17	0	0
11	105	130	167	190	194	192	207	254	267	271
12	30	77	95	119	130	118	158	160	198	205
	11/30		12/1		12/2		12/4		12/5	
13	20	0	0	0	38	0	0	0	0	30
14	20	0	0	0	45	0	0	0	0	0
15	41	79	87	101	133	128	130	163	194	209
16	10	0	168	0	98	196	0	305	308	403

TABLE 32: EXPERIMENTS VI AND VIII

TYPEWRITING OPTION: PRODUCT PRODUCED ON SUCCESSIVE HALF-DAYS BY SIXTEEN INDIVIDUALS

Individual	*A. M. 68° P. M. 75°*									
	9/14		9/15		9/16		9/17		9/18	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
1	49	0	59	0	107	20	0	0	61	0
2	859	0	471	432	625	250	302	0	225	551
3	195	12	242	130	403	316	169	16	199	240
4	368	10	240	0	300	0	170	15	236	0

TABLE 32—*Continued*

Individual	11/23		11/24		11/25		11/27		11/28	
	A. M. 68° P. M. 75°									
5	229	571	376	339	429	232	435	408	295	135
6	59	0	33	58	83	0	83	52	5	90
7	165	129	206	234	206	47	146	175	228	93
8	207	0	157	231	218	90	275	309	189	103
	A. M. 75° P. M. 68°									
	9/21		9/22		9/23		9/24		9/25	
9	254	924	440	635	762	1039	682	728	938	703
10	242	378	163	223	224	400	312	304	360	408
11	237	407	103	222	226	399	305	306	354	416
12	115	309	118	173	209	316	239	308	352	383
	11/30		12/1		12/2		12/4		12/5	
13	71	144	110	116	116	110	111	148	137	0
14	144	181	241	223	228	101	167	203	135	10
15	241	278	246	369	325	521	272	266	319	137
16	105	72	108	224	225	288	126	118	58	43

TABLE 33: EXPERIMENTS VI AND VIII

MENTAL MULTIPLICATION OPTION: PRODUCT PRODUCED ON SUCCESSIVE HALF-DAYS BY SIXTEEN INDIVIDUALS

Individual	9/28		9/29		9/30		10/1		10/2		10/3	
	First three days 68° Second three days 75°											
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
17	58	70	68	107	134	138	157	198	192	223	285	335
18	42	55	74	53	75	92	47	19	75	33	133	153
19	88	81	94	75	95	98	128	138	96	84	248	286
20	54	69	65	71	83	72	94	95	111	157	191	293
	11/9		11/10		11/11		11/12		11/13		11/14	
21	216	193	198	196	212	206	221	224	233	247	271	277
22	49	29	69	70	96	210	203	241	250	243	259	263
23	47	22	42	26	109	190	210	198	215	223	239	255
24	65	82	165	183	199	188	280	315	308	329	332	340
	First three days 75° Second three days 68°											
	10/5		10/6		10/7		10/8		10/9		10/10	
25	59	67	47	57	69	70	89	47	60	75	69	77
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	10	0	9	0	0
28	0	0	0	0	59	8	0	31	0	16	60	0
	11/16		11/17		11/18		11/19		11/20		11/21	
29	116	0	0	0	69	196	184	208	227	240	290	296
30	0	68	.165	140	199	221	220	224	255	241	278	274
31	124	147	103	78	220	196	163	196	223	215	237	256
32	187	0	95	98	227	219	221	224	235	217	300	300

TABLE 34: EXPERIMENTS VI AND VIII

Typewriting Option: Product Produced on Successive Half Days by Sixteen Individuals

First three days 68° Second three days 75°

	9/28		9/29		9/30		10/1		10/2		10/3	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
17	848	255	686	264	1275	1114	1027	489	1145	35	988	7
18	722	405	418	547	685	763	836	454	686	412	610	248
19	581	615	658	656	802	867	886	710	781	670	464	524
20	316	97	275	168	453	306	170	226	391	57	526	1
	11/9		11/10		11/11		11/12		11/13		11/14	
21	699	484	431	346	364	384	338	268	409	425	755	369
22	614	474	434	310	312	501	414	328	273	300	608	275
23	270	332	281	303	289	292	197	0	231	375	448	329
24	850	750	242	342	659	162	0	732	893	909	0	351

First three days 75° Second three days 68°

	10/5		10/6		10/7		10/8		10/9		10/10	
25	148	360	235	433	297	456	83	83	80	25	54	111
26	244	435	383	547	396	614	149	264	138	97	53	202
27	437	706	620	925	380	929	75	622	114	635	756	435
28	100	86	105	150	175	107	51	71	51	0	29	0
	11/16		11/17		11/18		11/19		11/20		11/21	
29	163	105	241	168	164	65	63	0	241	108	261	160
30	172	36	198	84	131	38	210	0	197	110	215	245
31	687	301	308	252	249	131	416	0	600	202	351	474
32	435	295	301	296	238	309	300	0	614	180	306	506

TABLE 35: EXPERIMENT XIV

MENTAL MULTIPLICATION OPTION: PRODUCT PRODUCED ON SUCCESSIVE HALF-DAYS BY EIGHT INDIVIDUALS (WOMEN)

Individual	A. M. 68°, 50%				P. M. 75°, 50%						A. M. 75°, 50%						P. M. 68°, 50%			
	5/3		5/4		5/5		5/6		5/7		5/10		5/11		5/12		5/13		5/14	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
33	82	70	182	190	216	214	220	218	242	264	242	226	280	224	286	292	304	348	330	376
34	134	96	164	158	162	200	204	236	276	262	120	272	274	232	358	372	374	352	376	474
35	106	128	160	174	158	172	184	194	238	242	230	268	288	278	340	364	386	368	312	396
36	40	120	130	156	56	232	258	88	92	0	226	220	238	238	360	222	310	0	224	386

	A. M. 75°, 50%				P. M. 68°, 50%						A. M. 68°, 50%						P. M. 75°, 50%			
	5/18		5/19		5/20		5/21		5/22		5/24		5/25		5/26		5/27		5/28	
37	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	14	0	0
38	0	42	94	0	36	0	158	0	158	0	152	0	140	0	42	180	168	0	116	0
39	0	0	200	0	264	0	272	0	270	0	338	0	396	0	348	0	406	172	456	0
40	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 36: EXPERIMENT XIV

TYPEWRITING OPTION: PRODUCT PRODUCED ON SUCCESSIVE HALF-DAYS BY EIGHT INDIVIDUALS (WOMEN)

Individual	A. M. 68°, 50%				P. M. 75°, 50%						A. M. 75°, 50%						P. M. 68°, 50%			
	5/3		5/4		5/5		5/6		5/7		5/10		5/11		5/12		5/13		5/14	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
33	208	279	332	337	349	385	336	373	337	372	364	465	414	482	435	495	485	548	378	376
34	149	150	230	210	289	315	263	101	263	6	131	300	207	0	73	5	263	0	0	474
35	159	179	267	237	292	304	300	250	303	0	330	303	349	0	360	314	332	67	0	396
36	159	137	256	260		299	299	97	273	166	332	346	343	28	370	137	274	134	66	386

	A. M. 75°, 50%				P. M. 68°, 50%						A. M. 75°, 50%						P. M. 68°, 50%			
	5/18		5/19		5/20		5/21		5/22		5/24		5/25		5/26		5/27		5/28	
37	96	145	131	142	208	200	200	109	135	172	213	171	233	156	231	149	0	325	478	0
38	123	154	193	208	268	221	334	203	236	183	244	279	282	339	341	339	366	361	354	0
39	274	300	311	268	337	386	435	384	295	293	392	443	497	392	485	435	482	505	418	0
40	386	330	345	432	503	605	520	422	281	475	291	508	566	479	573	400	573	364	577	56

TABLE 37: EXPERIMENT XIV

ADDITION OPTION: PRODUCT PRODUCED ON SUCCESSIVE HALF-DAYS BY EIGHT INDIVIDUALS (WOMEN)

	A. M. 68°, 50%				P. M. 75°, 50%						A. M. 75°, 50%						P. M. 68°, 50%			
	5/3		5/4		5/5		5/6		5/7		5/10		5/11		5/12		5/13		5/14	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
33	165	185	183	181	205	202	227	231	216	238	229	233	245	244	257	259	248	250	254	254
34	0	75	90	61	87	99	89	63	110	90	107	99	126	97	127	120	137	142	123	142
35	91	111	124	131	158	152	168	178	192	193	198	195	200	194	209	212	222	221	230	224
36	80	79	89	93	118	100	101	101	102	100	109	117	110	116	126	126	133	119	144	131

	A. M. 75°, 50%				P. M. 68°, 50%						A. M. 68°, 50%						P. M. 75°, 50%			
	5/18		5/19		5/20		5/21		5/22		5/24		5/25		5/26		5/27		5/28	
37	27	35	40	35	40	34	28	32	39	37	31	40	31	39	39	38	38	48	29	37
38	182	211	217	224	242	252	259	275	274	262	277	267	273	266	259	265	256	278	276	281
39	204	199	194	187	206	195	206	223	218	228	225	221	231	222	211	226	203	211	219	232
40	69	80	91	99	106	102	116	109	121	116	125	132	133	132	140	139	152	151	150	143

TABLE 38: EXPERIMENT XIV

MENTAL MULTIPLICATION OPTION: PRODUCT PRODUCED ON SUCCESSIVE HALF-DAYS BY SEVEN INDIVIDUALS (WOMEN)

	First Week, 68°, 50%										*Second Week, 75°, 50%*									
	6/1		6/2		6/3		6/4		6/5		6/7		6/8		6/9		6/10		6/11	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
41	24	0	22	14	74	60	62	38	54	78	70	48	70	96	74	74	88	72	46	70
42	26	50	30	34	40	60	66	50	50	60	68	70	78	70	60	50	60	60	70	70
43	0	14	2	16	30	0	54	32	48	52	74	80	62	56	56	60	70	56	52	64
44	16	0	6	38	42	46	50	94	80	78	98	94	75	90	94	98	98	88	94	96

	First Week, 75°, 50%										*Second Week, 68°, 50%.*									
	6/14		6/15		6/16		6/17		6/18		6/21		6/22		6/23		6/24		6/25	
45	22	26	82	44	18	96	66	56	20	58	50	64	56	62	68	52	72	66	74	48
46	110	44	60	70	108	88	50	66	58	50	48	110	80	50	128	38	60	94	48	50
47	78	18	28	30	54	58	54	48	72	56	34	58	44	110	88	20	66	86	84	56

TABLE 39: EXPERIMENT XIV

Typewriting Option: Product Produced on Successive Half-Days by Seven Individuals (Women)

	First Week, 68°, 50%.										*Second Week, 75°, 50%.*									
	6/1		6/2		6/3		6/4		6/5		6/7		6/8		6/9		6/10		6/11	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
41	173	283	329	313	354	405	389	457	419	507	511	597	523	460	550	512	406	445	347	547
42	182	265	268	285	299	309	311	326	317	338	378	385	256	335	346	339	295	440	504	436
43	172	242	243	335	308	393	279	320	310	423	347	337	460	455	234	291	305	505	305	323
44	85	112	125	174	189	218	215	224	194	283	306	279	306	287	317	278	214	297	243	340

	First Week, 75°, 50%.										*Second Week, 68°, 50%.*									
	6/14		6/15		6/16		6/17		6/18		6/21		6/22		6/23		6/24		6/25	
45	298	383	260	440	436	310	305	197	359	608	459	596	528	291	450	569	552	412	440	317
46	161	215	184	219	286	61	252	153	195	254	268	351	180	274	248	285	277	281	290	150
47	45	126	158	36	206	165	205	151	228	184	266	176	277	248	240	255	261	270	233	205

TABLE 40: EXPERIMENT XIV

Addition Option: Product Produced on Successive Half-Days by Seven Individuals (Women)

	First Week, 68°, 50%.										*Second Week, 75° 50%*									
	6/1		6/2		6/3		6/4		6/5		6/7		6/8		6/9		6/10		6/11	
	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.	A. M.	P. M.
41	139	141	168	160	166	181	180	183	185	209	212	189	218	211	219	202	224	233	229	210
42	68	86	96	114	127	131	128	129	132	132	137	142	139	153	159	143	154	112	157	143
43	64	89	85	104	104	104	124	123	135	130	139	156	138	158	152	165	157	168	165	166
44	47	56	64	59	74	74	81	78	74	83	92	85	100	96	105	107	119	111	112	116

	First Week, 75°, 50%.										*Second Week, 68°, 50%.*									
	6/14		6/15		6/16		6/17		6/18		6/21		6/22		6/23		6/24		6/25	
45	90	97	97	102	108	112	115	112	126	128	140	141	151	151	165	162	173	175	181	176
46	60	75	78	80	97	99	102	78	112	108	117	121	122	128	145	123	140	101	133	129
47	57	59	74	70	76	68	90	74	86	96	190	86	108	106	121	104	107	115	105	121

TABLE 41. SUMMARY OF RESULTS OF EXPERIMENTS VI, VIII AND XIV

EXPERIMENT VI: SECTION I: HALF-DAY CONDITION CHANGE

	68° 50% Stagnant	75° 50% Stagnant
Addition (Maximal)	60.3	57.9
Mental Multiplication (Option)	85.8	80.5
Typewriting (Option)	324.3	215.7
Comfort	3.7	4.2

EXPERIMENT VI: SECTION II: THREE-DAY CONDITION CHANGE

Addition (Maximal)	76.2	78.8
Mental Multiplication (Option)	51.1	87.4
Typewriting (Option)	371.9	450.3
Comfort	3.7	3.6

EXPERIMENT VIII: SECTION I: HALF-DAY CONDITION CHANGE

Addition (Maximal)	68.6	67.8
Mental Multiplication (Option)	200.8	212.7
Typewriting (Option)	189.4	169.5
Comfort	4.3	4.0

EXPERIMENT VIII: SECTION II: THREE-DAY CONDITION CHANGE

Addition (Maximal)	75.8	72.5
Mental Multiplication (Option)	183.2	190.5
Typewriting (Option)	330.9	304.0
Comfort	4.9	4.9

EXPERIMENT XIV: SECTION I: HALF-DAY CONDITION CHANGE

	68° 50% 30 cu. ft.	75° 50% 30 cu. ft.
Cancellation 2 (Maximal)	131.6	132.1
Cancellation 3 (Maximal)	147.6	148.9
Mental Multiplication (Option)	147.7	139.6
Addition (Option)	154.0	155.5
Typewriting (Option)	289.5	267.3
Comfort and Temperature vote	4.8— 28.1	4.6— 34.3

EXPERIMENT XIV: SECTION II: THREE-DAY CONDITION CHANGE

Cancellation 2 (Maximal)	133.2	138.1
Cancellation 3 (Maximal)	147.5	145.6
Mental Multiplication (Option)	52.6	64.5
Addition (Option)	123.1	123.3
Typewriting (Option)	302.9	306.0
Comfort and Temperature vote	4.6— 28.5	4.7— 37.3

SUMMARY AND INTERPRETATION

By E. L. THORNDIKE

With the forms of work and lengths of period used, we find that when an individual is urged to do his best he does as much, and does it as well, and improves as rapidly, in a hot, humid, stale, and stagnant air condition (86° F., 80% relative humidity, with no air or only recirculated air, and with no movement of the air save what is caused by events in the room and, in the case of recirculation, by the recirculating force) as in an optimum condition (68° F, 50% rel. hum., 45 cu. ft. per person per minute of outside air introduced). This result was obtained when the individuals were subjected to the bad conditions 4 hours a day for five consecutive days. Enough individuals were tested to make the result entirely reliable.

The same negative result has been obtained when the individuals were subjected to temperatures of 75° and 68° each for three successive days of 7 hours each.

Experiments subjecting individuals to the contrasted conditions for longer times (say, for sixty working days of 8 hours each or a half-year of school days of five hours each) are desirable. It is hoped that the importance of the results just mentioned will lead someone who has the facilities, to make such experiments. The hot conditions cause a relative rise in body temperature and quickening of the pulse as well as the various annoying sensory conditions due to the heat and perspiration. These may have an effect when continued week after week that they do not display over a short period.

We find further that when an individual is given work to do that is of no interest or value to him and is deprived even of means of telling how well he does do it, and is in other ways tempted to relax standards and do work of a poor quality, he still shows no inferiority in the quality of the product produced in stagnant air at 86°, 80% r. h., with 30 to 40 parts of CO_2 per 10,000, he being subjected to this condition for 8 hours a day for four successive days, and tested on the second, third, and fourth day. There is some evidence that he spends more time on the work, but even this is not certain.

Finally, we find that when an individual is left to his (or her) own choice as to whether he shall do mental work or read stories, rest, talk, or sleep, he does as much work per hour when the temperature is 75° as when it is 68°. In the experiments on this topic, temperature alone was varied, other air conditions being kept constant. The reason for this limitation was the apparent absence in all the experiments to date, of any physiological effects due to staleness of the air as shown by high CO_2 content. The smaller difference was chosen to make the experiments suitable for their main purpose as a test of certain conditions upon appetite, the psychological tests being in this case secondary. It is also the case that the effect of moderate over-heating upon the inclination to do mental work is, in practice, more important than the effect of extreme heat. The two conditions (68° and 75°) were maintained each for three successive days of seven hours each.

In a very short experiment wherein the temperature was varied to 86° F., 80% rel. hum., there did seem to be a diminished inclination to do mental work, but the variability of results in all such experiments with optional work advises us to postpone any conclusion concerning the effect of very high temperatures upon inclination until adequate experiments are made.

These results are obviously in sharp contrast to the expectations from the ordinary discussions of ventilation in text-books and the like. The common view used to be that air was "good" as in the open country and "bad" as in a sealed, crowded room; and that bad air was bad for the body and mind as a whole. A less mystical view has been that hot and stagnant air is inevitably enervating and depressing to the mind, causing thought and action to be less rapid, accurate, and suitable to their ends. The former view need not be discussed here until its advocates produce some evidence of the fitness of good air as a condition of effective thought beyond the fragrance of the air and their enjoyment of it. If their own logic is a fair specimen of the thinking to which "pure" air predisposes man, we may perhaps prefer the defiled mixture of libraries and laboratories! The second view seems to be supported by many experiences of daily life and it is perhaps desirable to make certain suggestions concerning the reconciliation of our experimental results and these experiences.

The first concerns the difference between the presence and strength of certain connections or lines of little resistance for conduction in

the brain, and the excitability or readiness of these connections to conduct. There seems to be such a difference, though the detailed physiology of it is hypothetical. Long repeated conduction over a connection seems to strengthen the connection but make it less ready to act. Rest seems to weaken a connection but makes it more ready to act. Certain diseases seem to reduce readiness enormously without much altering the actual strength of the connections. The phenomena of refractory periods seem to require some such double form of action in the nervous system. To outside observation the existence and strength of neural connections is witnessed in memory, thought, and skill. The readiness of conduction units to conduct is witnessed by interest and satisfyingness of the thinking or action. It is, of course, hard to distinguish between the satisfyingness or intolerability of the thinking or action itself and that of the accompanying conditions, but experimental analysis can probably generally decide correctly.

When a person does less mental work or does the work less well in hot, stale, stagnant air, the cause might be (1) that the strength of the neural connections by whose action mental products are produced was weakened; or (2) that, their strength being unimpaired, they were, by changes within themselves, less ready to act; or (3) that, though no intrinsic change in them had occurred, the person responded to the discomforts of a hot skin, flushed face, sticky body and the like, by relaxing or intermitting mental work. In the first case, the person could not think or act as well in bad as in good air if he would. In the second case, he could think as well, but would gain in comfort if he relaxed or intermitted the unsatisfying activity, more in bad air and less in good air. In the third case he could think as well, and would be no less comfortable if he did maintain mental activity as much in bad air as in good air.

The bad conditions of the air tested in our experiments did not seem to reduce the strength of neural connections at all. Nor can I see any reason why they should. The brain does not get enough hotter in a room at 86° 80% to lead us to expect any considerable disturbance in associative strength. Nor did the bad conditions seem to alter the intrinsic readiness to conduct of the conduction units involved in adding, multiplying, and the other functions tested. Had they done so, the subjects in the experiment with judgments should have responded to the bad conditions by a relative relaxation of the care with which they examined specimens and rated them.

What the hot conditions demonstrably did do was to make the subjects feel uncomfortable. The positive effect on their reports of how well they felt is in striking contrast to the zero effect on how well they did. In ordinary life, they might have sought relief from the hot stickiness of the 86° 80% condition by relaxing the mental work, leaving part of it to be done when it was cooler; or might have omitted the work altogether by the plea that it was too hot to work. But they might thereby have gained nothing if in the end the work had been some time done. On the contrary they might have gained in enjoyment by using the hot periods for mental work and cooler periods for recreation.

It may be, that is, that the custom of relaxing or intermitting mental work in response to hot skin, flushed face, perspiring body, and the like gives no evidence that mental work is any more taxing or injurious then than at cooler periods. The higher body-temperature, quicker pulse, and sensory discomforts probably are taxing, but we lack evidence that their presence makes the same mental productivity different in its nature or consequences from what it is in cool air. The discomforts to which men have responded by ceasing mental work might perhaps better be responded to by working to pay for an electric fan, taking cool baths, or thinking out ways to reduce the physical exertions which accentuate the discomforts. Merely to postpone useful thought to a cooler period may leave the net total of discomfort unchanged or even increase it.

The custom of relaxing mental work in hot temperatures is not then a proof that such relaxation is necessary or wise, nor irreconcilable with our experimental results.

Consider now the two special cases of summer heat and crowded rooms. We take vacations in hot rather than in cold weather. Many of us do not demand as much mental work from ourselves, our employees, or our pupils in the hot as in the cold season. Can this be explained without assuming that heat is really depressing, reducing the ability to do mental work or at least reducing the intrinsic satisfyingness of the work and so, if equal work is done, demanding greater strain?

The dating of vacations for children may be a relic from a time when they were taken out of school at such time as their services would be of use; and the dating of vacations for adults seems to depend upon the superiority of the summer for play as well as its inferiority for work; and to depend upon the value of release from

the general discomforts of heat rather than the value of release from mental work. In any arguments concerning summer heat, also, the debilitating effects of certain diseases then prevalent and of lack of sleep must be considered. The present writer, in view of the experiences of the summer schools maintained in connection with our universities and normal schools, is skeptical of the assumption that summer temperatures of 70° to 85° with their high humidities are, in and of themselves, unfavorable to mental work.

Given x units of mental product to be produced in a year and assuming that the opportunities for recreation are equally attractive in all months, it seems possible that the slackening of mental work in the hot months might be of little or no use.

After spending time in a crowded room many individuals feel unfit to do mental work. Dullness, mental inertia, sleepiness, and headache are reputed consequences. And these are commonly attributed to the air. They may be due to the air, but we should also scrutinize the other conditions that usually accompany the spending of time in crowded rooms as at parties, theatres, shopping tours, and the like. These are late hours, nervous excitement, uncomfortable clothes, and uncomfortable posture in the case of crowded public conveyances. Improper eating is often a secondary comcomitant. Dullness, mental inertia, sleepiness, and headache used to be attributed unquestionably to the chemical constitution of the air breathed in crowded rooms due to its having been breathed before. This orthodox view of the recent past is now discarded as fantastic, the harm being now attributed to the heat and stagnancy of the air as it meets our skins. But conceivably our skins might be as little to blame as our lungs. Until the total situation of the crowded room is analyzed experimentally with due attention to the sensory over-stimulations, the excitement and worry, the social contacts, the indulgence in foods and drinks, the lack of sleep and other nervous strains, the evidence that the air of a crowded room makes man unable or unwilling to do mental work is incomplete.

Moreover, there are some facts which reduce the general probability that the heat of the air is *per se* the cause of the reported dullness, inertia, and sleepiness. Physical exercise outdoors under the "best" air-conditions makes many persons duller and more inert than does an equal amount of time spent quietly in a hot ill-ventilated room. The heat of crowded rooms is said to make one sleepy, but the same heat during a summer night is said to keep one from sleep.

On the whole, then, the experiences of daily life may conceivably be entirely consistent with the absence of any effect of bad air (within the range of temperature and length of continuance of our experiments) upon the ability to do mental work, and with the absence of any effect of a 68° to 75° temperature difference upon the readiness to do mental work. When heat reduces mental work it may do so *via* the general discomforts which it causes rather than by any intrinsic disability or unreadiness in the process of mental production itself.

Our experiments, however, need repetition and extension. In particular the effects upon mental efficiency of slight elevations of body temperature (from ¼ to 1¼ degrees Fahrenheit) and of perspiration need to be studied. The experiences of daily life need to be analyzed into their elements, and the separate effect of each element determined.

It will be understood that the remote effects of hot, humid, stagnant air upon mental efficiency—as by producing susceptibility to disease, by depriving the body of exercise, or by fostering bad habits of diet or sleep, are not considered in this monograph. They are beyond the scope of our experiments. It should also be remembered that our experiments and the entire argument so far concerns only short exposures mostly of from four or eight hours continued daily for from three to five days. It should finally be noted that the problem of odor and its influences upon mental work has also been left outside the range of our experiments. Whether the odor in closed rooms is simply offensive to certain refined ideals or is essentially injurious to mental achievement, we have made no effort to decide. We can only say that such odors as were caused under the experimental conditions used did not apparently decrease either the ability or the willingness to do mental work.

APPENDIX

Following are instructions given to the subjects of the experiments in the preliminary practice and for their direction during the tests.

Color-Naming

The subject will be provided with a color blank. The object of the experiment is to name each color as rapidly as possible. Care must be taken that the subject starts with the sheet in the right position. This position will be shown on each occasion by the experimenter.

The procedure will be as follows: The sheet should be laid face downwards; at the given signal the paper must be reversed, so as to reveal the colors. These should be named in succession as quickly as possible, reading from left to right. In case of any misnaming of a color, the subject will be stopped, and made to go back to the point at which the mistake arose.

The time taken to name the complete series will be measured, the object is to make this time a minimum.

Cancellation

The subject will be provided with a cancellation sheet. In this sheet a certain specified number must be cancelled throughout. The object of the experiment is to omit as few cases of the specified number as possible, and to complete a maximum amount of cancellation in the time allowed.

The procedure of the experiment is as follows: After writing your name on the sheet, lay it face downwards. On the signal being given to reverse the sheet, commence to cancel, proceeding with this until the signal to stop is given, at which time work must cease immediately. The method of counting is shown below:

2 (number cancelled correctly), minus 2 (number omitted), minus 3 (numbers wrongly marked).

From this method of measurement, it will be noticed that additional speed can outweigh complete accuracy. The object of the subject is to score the maximum amount under these known conditions.

Example.—Suppose that you had to cross off 3 or 5 from the list: 134854720 5823405895612338403749015932649362798016 42.

Opposites

The subject will be provided with a list of words of which the opposites must be named, a certain range of choice of opposites being allowed.

The procedure is as follows: The paper should be laid face downwards and reversed at the given signal. Opposites should then be given to each word in the first column, and when this column is completed, to those in the second column. At any time when more than 15 seconds is taken for any particular opposite, the subject will be told what the opposite is. The object of the experiment is to complete the list in the minimum time.

Examples:

good	bad
rich	poor
high	low
roughly	smoothly

Addition

You will be given a sheet containing columns of one-place numbers like those shown below:

8	6	9
5	5	7
6	9	5
4	6	7
9	2	3
2	3	5
5	7	3
4	5	8
8	9	9
6	4	2

This will be placed before you bottom side up. When the experimenter says "Go," you will turn the sheet over and add, writing the sum of each column of 10 figures as fast as you can but without making errors. If an answer is wrong, you will receive no credit for that column. When you finish the examples on one sheet take another.

Instructions for Work in the Mental Multiplication of a Three-place Number by a Three-place Number. Used in Experiments I, II, VI and VIII

The work is to be done *mentally*, nothing being written down until the entire product is obtained. You may say the numbers, the partial products or anything else to yourself silently but nothing is to be spoken out loud or whispered. You will proceed as follows:

Suppose the example is 235; you will multiply 235 by 2, remembering
632

meanwhile that the entire multiplier is 632. Having got the 470, fix it mind. Then multiply 235 by 3 and when you get the 705 add it to 470 remembering that 705 counts as 7050 in adding. As soon as you have 7520, fix it in mind, when you can forget all else except the 235 to be multiplied by 6. Hold 7520 in mind while you get 6 times 235, which is 1410. Now you can forget everything else except the 7520 and the 1410 which counts as 141,000 in adding. As soon as you have added and got the 148,520, write it down.

Besides doing the work in the manner described above, you are to record the time in hours, minutes and seconds when you begin each example. Should a rest be allowed between two examples, record the time of finishing the last example.

The score is a composite of your speed and your accuracy. It will be the number of examples done, minus 1/10th of an example for one wrong figure in the answer, 2/10ths for two wrong figures, 3/10ths for three wrong figures and 5/10ths for four wrong figures and 10/10ths for five or more wrong figures. It is then necessary to work carefully enough to avoid more than an occasional error in order to make a good score.

Practise first at the mental multiplication of a three-place number by a two-place number and when you get so that you make but few mistakes, proceed to the multiplication of a three-place number by a three-place number.

Instructions for Work in the Mental Multiplication of a Three-place by a Two-place Number. Used in Experiment XIV

The work is to be done *mentally*, nothing being written down until the entire product is obtained. You may say the numbers, the partial products, or

anything else, to yourself silently. You will proceed as follows: Suppose the example is 235. Multiply 235 by 2. Having got the 470, you will
32

fix it in mind. Then multiply 235 by 3, remembering the 470 and when you get the 705, add it to the 470 remembering that 705 counts as 7050 in adding. As soon as you have the 7520, write down 7520 beneath the example.

Besides doing the work in the manner described above, you are to record the time in hours, minutes and seconds, at which you begin each example.

In all this work your aim should be to make the best possible score. The score is, of course, a composite of your speed and accuracy, and will be kept as follows: The number of examples done times 10 minus 2 for each wrong figure in each answer. That is, if all the figures in a five-place answer are wrong you get zero credit; if two are wrong, you get three-fifths credit, etc. You should therefore work carefully so as only very rarely to have errors in any answer. Practise with the following examples to get an idea of how rapidly you can work without making more than an occasional error. Score the time separately for each one and note whether you make any errors in each before proceeding to the next.

(1)	(2)	(3)	(4)	(5)
427	682	723	386	965
53	47	85	92	38

Score for practice set:

Time for No. 1, min....sec....Wrong figures in answer....
" " " 2, " .... " ... " " " " ....
" " " 3, " .... " ... " " " " ....
" " " 4, " .... " ... " " " " ....
" " " 5, " .... " ... " " " " ....

Typewriting Instruction Sheet

If you do not already know how to use the typewriter keys, shift-key, spacer, and so on, ask to be shown.

The score in typewriting will be the number of lines that you can copy, with one tenth of a line taken off for each wrong letter or wrong space. If you make a mistake, do not go back to correct it, but continue copying.

Instructions for Grading Specimens of Handwriting

Look at each specimen. Give it a grade 4, 4.1, 4.2, 4.3, 4.4, etc., up to 20 20.1, 20.2, 20.3, etc., according to its general merit as handwriting in comparison with the specimens of the Scale. Record the grade you assign to each specimen on the record sheet. Pay no attention to the apparent age or training of the person who wrote the specimen nor the apparent speed at which it was written. Grade the specimen itself, disregarding whatever you may think concerning who wrote it, or how it was written. Grade to a first decimal as noted above.

Instructions for Grading English Compositions

Read through the Hillegas Scale and get an idea of the quality of a composition that has a value of 20, 30, 40, etc. Read each composition and assign to it a mark for general merit in accordance with the Scale. Let general merit mean whatever combination of thought, style and formal correctness you think general merit does involve. Pay no attention to the apparent age or training of the person who wrote the composition. Grade the composition itself, disregarding whatever you may think concerning who wrote it or how it was written. Use 10, 11, 12, 13, etc., up to 97, 98, 99, 100, 101, 102, etc., etc., as grades. Do not try to grade to a decimal fraction nor to the figures on the scale. You must, however, let the scale fix your values in general.

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